User's Manual

Model 460

3-Channel Gaussmeter

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Rev. 2.3 P/N 119-012 **6 May 2004**

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DECLARATION OF CONFORMITY

CE

We: **Lake Shore Cryotronics, Inc.**
575 McCorkle Blvd.
Westerville OH 43082-8888 USA

hereby declare that the equipment specified conforms to the following Directives and Standards:

Application of Council Directives: **73/23/EEC**
89/336/EEC

Standard to which Conformity is declared: ..... **EN 61010-1:2001**
Overvoltage II
Pollution Degree 2
EN 61326 A2:2001
Class A
Annex B

Model Number: **460**

Ed Maloof 1-7-2004

_____ _____
Signature *Date*

Ed Maloof
Printed Name

Vice President of Engineering
Position

Electromagnetic Compatibility (EMC) for the Model 460 3-Channel Gaussmeter

Electromagnetic Compatibility (EMC) of electronic equipment is a growing concern worldwide. Emissions of and immunity to electromagnetic interference is now part of the design and manufacture of most electronics. To qualify for the CE Mark, the Model 460 meets or exceeds the generic requirements of the European EMC Directive 89/336/EEC as a **CLASS A** product. A CLASS A product is allowed to radiate more RF than a CLASS B product and must include the following warning:

WARNING: This is a CLASS A product. In a domestic environment, this product may cause radio interference in which case the user may be required to take adequate measures.

The instrument was tested under normal operating conditions with sensor and interface cables attached. If the installation and operating instructions in the User's Manual are followed, there should be no degradation in EMC performance.

Pay special attention to instrument cabling. Improperly installed cabling may defeat even the best EMC protection. For the best performance from any precision instrument, follow the grounding and shielding instructions in the User's Manual. In addition, the installer of the Model 460 should consider the following:

- Leave no unused or unterminated cables attached to the instrument.
- Make cable runs as short and direct as possible.
- Do not tightly bundle cables that carry different types of signals.
- Add the clamp-on ferrite filter (Part Number 109-053) included with the connector kit to the serial interface cable near the instrument rear panel when that interface is used.

TABLE OF CONTENTS

Chapter/Paragraph	Title	Page
1	**INTRODUCTION**	**1-1**
1.0	General	1-1
1.1	Product Description	1-1
1.2	Specifications	1-4
1.3	Safety Summary	1-5
1.4	Safety Symbols	1-5
2	**INSTALLATION**	**2-1**
2.0	General	2-1
2.1	Inspection and Unpacking	2-1
2.2	Repackaging For Shipment	2-1
2.3	Rear Panel Definition	2-2
2.4	Line Input Assembly	2-3
2.4.1	Line Voltage and Fuse Verification	2-3
2.4.2	Power Cord	2-3
2.4.3	Power Switch	2-3
2.5	Probe Input Connection	2-3
2.5.1	Attachment To A Hall Generator	2-4
2.6	Corrected and Monitor Analog Outputs	2-4
2.7	Initial Setup and System Checkout Procedure	2-4
3	**OPERATION**	**3-1**
3.0	General	3-1
3.1	Definition of Front Panel Controls	3-1
3.1.1	Front Panel Keypad Definitions	3-1
3.1.2	Front Panel Display	3-3
3.1.3	Front Panel Navigation	3-4
3.1.4	Channel On/Off	3-4
3.1.5	Vector Source	3-5
3.2	Max Hold and Max Reset	3-5
3.3	Zero Probe	3-6
3.4	Select Range and Auto Range	3-7
3.5	AC/DC and Peak/RMS	3-8
3.6	Filter	3-9
3.7	Field and Temperature Compensation	3-11
3.8	Gauss/Tesla	3-11
3.9	Relative Set and Relative On/Off	3-12
3.10	Alarm Set and Alarm On/Off	3-13
3.11	Local and Interface	3-16
3.12	Display	3-17
3.13	Analog Out	3-17
3.13.1	Corrected Analog Out	3-17
3.13.2	Monitor Analog Out	3-20
3.14	Locking and Unlocking the Keyboard	3-21
3.15	Factory Default Settings	3-22
3.16	Special Functions	3-22
3.16.1	Fast Data Acquisition Mode	3-22
3.16.2	Analog Output Control Mode	3-23
3.16.3	Sleep Mode	3-23
3.17	Probe Considerations	3-24
3.17.1	Changing Probes	3-24
3.17.2	Probe Handling	3-25
3.17.3	Probe Polarity	3-26
3.17.4	Probe Accuracy Considerations	3-27
4	**COMPUTER INTERFACE OPERATION**	**4-1**
4.0	GENERAL	4-1
4.1	IEEE-488 INTERFACE	4-1
4.1.1	Changing IEEE-488 Interface Parameters	4-2
4.1.2	IEEE-488 Command Structure	4-2
4.1.2.1	Bus Control Commands	4-2
4.1.2.2	Common Commands	4-3
4.1.2.3	Device Specific Commands	4-3

TABLE OF CONTENTS (Continued)

Chapter/Paragraph	Title	Page
4.1.2.4	Message Strings	4-3
4.1.3	Status Registers	4-4
4.1.3.1	Status Byte Register and Service Request Register	4-4
4.1.3.2	Standard Event Status Register and Standard Event Status Enable Register	4-4
4.1.4	IEEE Interface Example Programs	4-5
4.1.4.1	IEEE-488 Interface Board Installation for Visual Basic Program	4-5
4.1.4.2	Visual Basic IEEE-488 Interface Program Setup	4-7
4.1.4.3	IEEE-488 Interface Board Installation for Quick Basic Program	4-10
4.1.4.4	Quick Basic Program	4-10
4.1.4.5	Program Operation	4-13
4.1.5	Troubleshooting	4-13
4.2	Serial Interface Overview	4-14
4.2.1	Physical Connection	4-14
4.2.2	Hardware Support	4-15
4.2.3	Character Format	4-15
4.2.4	Message Strings	4-15
4.2.5	Message Flow Control	4-16
4.2.6	Changing Baud Rate	4-16
4.2.7	Serial Interface Basic Programs	4-17
4.2.7.1	Visual Basic Serial Interface Program Setup	4-17
4.2.7.2	Quick Basic Serial Interface Program Setup	4-20
4.2.8	Trouble Shooting	4-22
4.3	Command Summary	4-22
4.3.1	Common Commands	4-24
4.3.2	Interface Commands	4-27
4.3.3	Device Specific Commands	4-30
4.3.4	Probe Specific Commands	4-39
5	**ACCESSORIES AND PROBES**	**5-1**
5.0	General	5-1
5.1	Models	5-1
5.2	Accessories	5-1
5.3	Lake Shore Standard Probes	5-3
5.3.1	Probe Selection Criteria	5-3
5.3.2	Radiation Effects on Gaussmeter Probes	5-3
5.3.3	2-Axis and 3-Axis Probes	5-4
5.3.4	Probe Specifications	5-4
5.4	Helmholtz Coil Low Field Standards	5-10
5.5	Reference Magnets	5-12
6	**SERVICE**	**6-1**
6.0	General	6-1
6.1	General Maintenance Precautions	6-1
6.2	Electrostatic Discharge	6-1
6.2.1	Identification Of Electrostatic Discharge Sensitive Components	6-2
6.2.2	Handling Electrostatic Discharge Sensitive Components	6-2
6.3	Line Voltage Selection	6-2
6.4	Fuse Replacement	6-3
6.5	Rear Panel Connector Definitions	6-4
6.5.1	IEEE-488 Interface Connector	6-5
6.6	Optional Serial Interface Cable And Adapters	6-6
6.7	Operating Software Eprom Replacement	6-7
6.8	Error Messages	6-8
APPENDIX A – GLOSSARY OF TERMINOLOGY		**A-1**
APPENDIX B – UNITS FOR MAGNETIC PROPERTIES		**B-1**
APPENDIX C – HALL GENERATORS		**C-1**
C1.0	General	C-1
C2.0	Theory of Operation	C-1
C3.0	Hall Generator Generic Hookup	C-3
C4.0	Using a Hall Generator with the Model 460	C-4
C5.0	Specifications	C-5
C6.0	HALLCAL.EXE Program	C-8

LIST OF ILLUSTRATIONS

Figure No.	*Title*	*Page*
1-1	Model 460 Front Panel	1-1
1-2	Various Model 460 Probe Configurations	1-3
2-1	Model 460 Rear Panel	2-2
2-2	Line Input Assembly	2-3
2-3	Model MCBL-XX User Programmable Cable Accessory	2-4
3-1	Model 460 Front Panel	3-1
3-2	Front Panel Display Definition	3-3
3-3	Display Filter Response Examples	3-10
3-4	Monitor Analog Output Frequency Response	3-20
3-5	Maximum Flexible Probe Bend Radius	3-25
3-6	Probe Orientation For Positive Measurement	3-26
3-7	Effect Of Angle On Measurements	3-27
4-1	GPIB Setting Configuration	4-6
4-2	DEV 12 Device Template Configuration	4-6
4-3	Typical National Instruments GPIB Configuration from IBCONF.EXE	4-11
4-4	Serial Interface Adapters	4-14
5-1	2-Axis Probe Tip Details	5-4
5-2	3-Axis Probe Tip Details	5-5
5-3	Definition of Lake Shore Gamma Probe	5-5
5-4	Definition of Lake Shore 2- and 3-Axis Probes	5-6
5-5	Definition of Lake Shore Robust (Brass Stem) Probes	5-6
5-6	Definition of Lake Shore Transverse Probes	5-7
5-7	Definition of Lake Shore Tangential Probe	5-7
5-8	Definition of Lake Shore Axial Probes	5-8
5-9	Definition of Lake Shore Flexible Transverse Probes	5-9
5-10	Definition of Lake Shore Flexible Axial Probe	5-9
5-11	Model MH-2.5 Helmholtz Coil	5-10
5-12	Model MH-6 Helmholtz Coil	5-11
5-13	Model MH-12 Helmholtz Coil	5-11
5-14	Lake Shore Reference Magnets	5-12
5-15	Model 4060 Zero Gauss Chamber	5-13
5-16	Model 4065 Large Zero Gauss Chamber	5-13
5-17	Model 4001 RJ-11 Cable Assembly	5-14
5-18	Model 4002 RJ-11 to DB-25 Adapter	5-14
5-19	Model 4003 RJ-11 to DE-9 Adapter	5-14
6-1	Power Fuse Access	6-3
6-2	PROBE INPUT Connector Details	6-4
6-3	ANALOG OUT Corrected and Monitor BNC Connector Details	6-4
6-4	SERIAL I/O Connector Details	6-4
6-5	IEEE-488 Rear Panel Connector Details	6-5
6-6	Model 4001 RJ-11 Cable Assembly Wiring Details	6-6
6-7	Model 4002 RJ-11 to DB-25 Adapter Wiring Details	6-6
6-8	Model 4003 RJ-11 to DE-9 Adapter Wiring Details	6-6
6-9	Location Of Operating Software EPROM	6-7
C-1	Hall Generator Theory	C-2
C-2	Axial and Transverse Configurations	C-2
C-3	Typical Hall Generator Hookup	C-4
C-4	Hall Generator Input Impedance	C-4
C-5	Axial Hall Generator HGA-3010, HGA-3030, & HGCA-3010 Dimensions	C-5
C-6	Transverse Hall Generator HGT-3010, HGT-3030, & HGCT-3020 Dimensions	C-5
C-7	Transverse Hall Generator HGT-1010 Dimensions	C-6

LIST OF TABLES

Table No.	*Title*	*Page*
4-1	IEEE-488 Interface Program Control Properties	4-8
4-2	Visual Basic IEEE-488 Interface Program	4-9
4-3	Quick Basic IEEE-488 Interface Program	4-12
4-4	Serial Interface Specifications	4-15
4-5	Serial Interface Program Control Properties	4-18
4-6	Visual Basic Serial Interface Program	4-19
4-7	Quick Basic Serial Interface Program	4-20
4-8	Command Summary	4-23
B-1	Conversion from CGS to SI Units	B-1
B-2	Recommended SI Values for Physical Constants	B-2
C-1	Cryogenic Hall Generator Specifications	C-5
C-2	Axial Hall Generator Specifications	C-6
C-3	Transverse Hall Generator Specifications	C-7

CHAPTER 1

INTRODUCTION

1.0 GENERAL

Lake Shore Cryotronics designed and manufactured the Model 460 3-Channel Gaussmeter in the United States of America. The Model 460 is a high-accuracy, full-featured gaussmeter ideally suited for the laboratory. Model 460 features include:

- 3 Axis or 3 Independent Channels
- Displays Each Axis Simultaneously
- Vector Magnitude Reading
- Resolution to 5¾ Digits
- Accuracy to ±0.10% of Reading
- Peak Capture
- Analog Voltage Outputs
- IEEE-488 and Serial Interface

1.1 PRODUCT DESCRIPTION

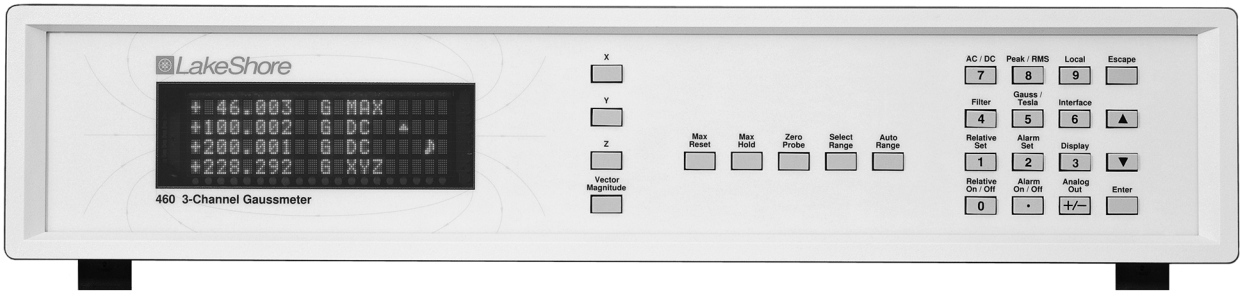
The Model 460 three-channel Hall effect gaussmeter is the best choice for applications requiring three axis measurements or three simultaneous single axis measurements. This instrument combines the performance of three Model 450 Gaussmeters into one package, making it an excellent value. The large display shows readings for all three channels simultaneously. The fourth display can be used to show Vector Magnitude when necessary.

Probes

The Lake Shore strength in magnetic measurement instrumentation is rooted in the ability to make Hall effect sensors and probes. This strength is most apparent when multiple axis measurements are required. The Model 460 is optimized for use with Lake Shore two- and three-axis probes as well as standard Hall sensors, single axis probes, and probe accessories. The instrument automatically reads data stored in the probe connector to identify probe type and capability. If standard products are not sufficient, custom probes and assemblies are can be made to order.

Measurement Features

Easy access to probe information that is stored in the probe allows several features which improve the measurement capability of the instrument. Probe type tells the instrument how to configure itself for multiple axis measurements and what field ranges are available for display, autorange, and automatic probe zero. With a factory calibrated linearization table, the instrument can compensate for inherent nonlinearity in the sensor and calculate the field more accurately than a single point sensitivity would allow. If the probe is equipped with a temperature sensor, the Model 460 reads temperature along with the field signal and makes continuous adjustments to the calculated field value. Vector magnitude calculations can be done by the instrument when using two- and three-axis probes.



460_Front.bmp

Figure 1-1. Model 460 Front Panel

Product Description (Continued)

Measurement Modes

The Model 460 has three operating modes: DC, RMS, and Peak. The instrument is well suited for DC measurements because accuracy and resolution are best in DC mode. Noise floor is so low that 5¾ digit measurements are possible.

Low noise and high stability are ideal for multiple axis field mapping applications. Changing fields, which are often used in material analysis systems, can be measured on all three inputs up to 18 times a second over a computer interface with full resolution.

In RMS mode the Model 460 can measure periodic AC fields from 10 to 400 Hertz. True RMS conversion is done by instrument circuitry that accommodates wave forms with crest factors up to 7. RMS mode is best suited for measuring fields surrounding linear power supplies or solenoids driven at line frequency.

Peak circuitry in the Model 460 can capture single-event peaks or monitor the peak amplitude of periodic wave forms. Reproducible single-peak measurements can be made down to 5 ms. Three independent peak circuits allow simultaneous capture of all three inputs. Instrument software enables an indefinite hold time with no decay. Periodic peak measurements can be made over the same frequency range as RMS wave forms. If faster peak or RMS measurements are required, the Lake Shore Model 480 Fluxmeter has a wider frequency range.

Range and Resolution

Hall effect gaussmeters are popular in part because of their ability to measure field over a broad range. With appropriate probes, the Model 460 has full-scale ranges from 300 mG to 300 kG. A different range can be used with each input. With 5¾-digit resolution, DC field variations approaching 0.010 mG can be detected. In larger DC fields, resolution of 1 part in 300,000 can be achieved. RMS and peak measurements are limited to 4¾ digits or 1 part in 30,000 resolution because environmental noise is more difficult to separate from desired signal in those modes. The filter feature can be used to improve resolution in noisy environments by taking a running average of field readings in DC or RMS modes.

Interface

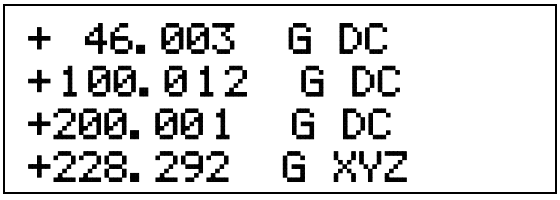
There are two computer interfaces included with the Model 460: parallel IEEE-488 and serial RS-232C. Either interface can send instrument setup commands and query field reading data. The maximum reading rate of the instrument can be achieved using the IEEE-488 interface. Nearly every function of the instrument front panel can be performed over the computer interface.

Two types of analog voltage outputs are also included with the Model 460. The single Corrected Analog Output is a DC voltage proportional to the display reading. It is generated using a D/A converter programmed at the instrument update rate. Available software error correction and vector calculations can be used when generating the corrected output voltage. Three Monitor outputs are real-time analog voltages proportional to the field at each input. These outputs do not have the advantage of software correction but are much faster than the Corrected output with the full DC to 400 Hertz bandwidth.

Operation

The Model 460 has several software features intended to make multi-axis field measurements more convenient. A bright four line vacuum fluorescent display and full function keypad provide easy access to these features and give meaningful feedback.

X, Y, and Z Axis with Vector Magnitude



The Model 460 can display each axis simultaneously plus Vector Magnitude XYZ = $(X^2 + Y^2 + Z^2)^{1/2}$.

Product Description (Continued)

X and Y Axis with Differential Reading

```
+105.628  G DC
+ 83.415  G DC

+ 22.213  G X-Y
```

Differential readings ($X - Z = X_{reading} - Y_{reading}$) are possible with the Model 460.

X, Y, and Z Axis with Max Hold on Vector Magnitude

```
+ 58.190  G DC
+109.752  G DC
+198.251  G DC
+215.936  G MAX
```

X, Y, and Z Channels as 3 Separate Gaussmeters

```
+213.524  G DC    ♪
+  5.067  G RMS
+ 17.374 kG PK
```

This is a 3-channel gaussmeter. It can be used as 3 separate gaussmeters, a 2-axis and single channel gaussmeter, or a 3-axis gaussmeter.

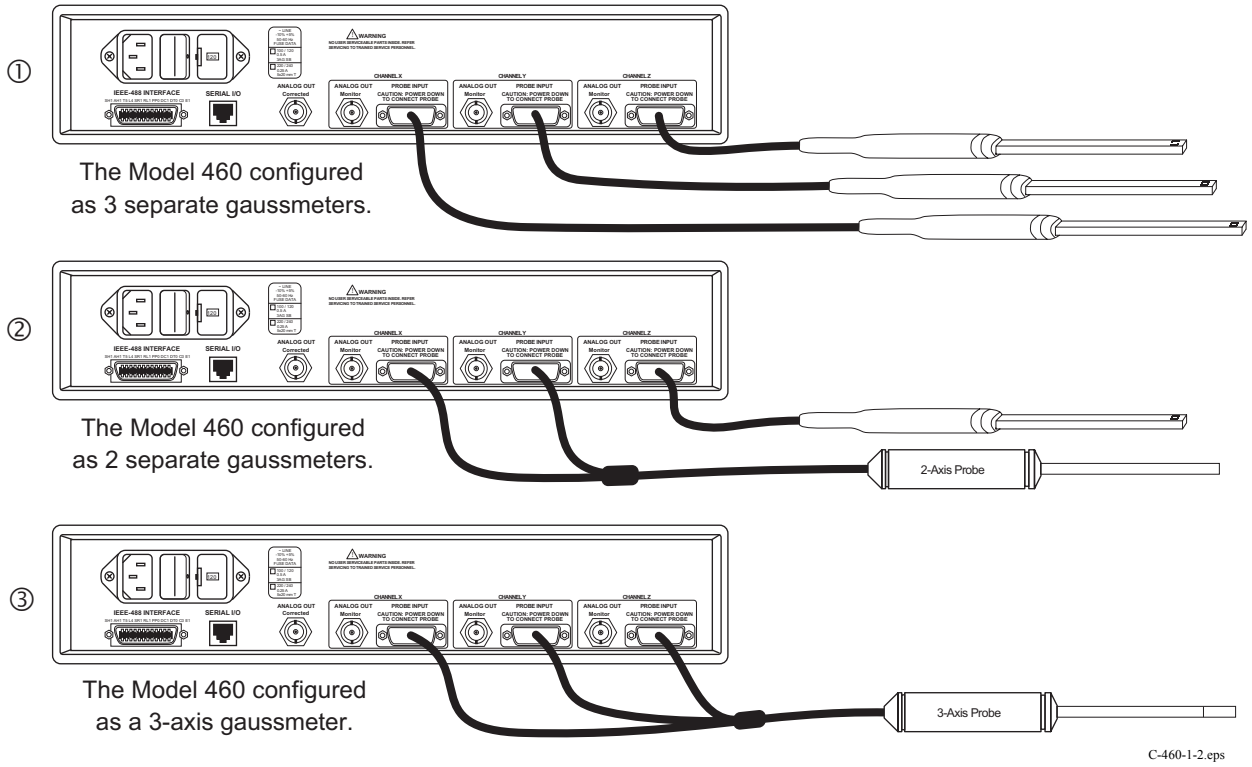


Figure 1-2. Various Model 460 Probe Configurations

1.2 SPECIFICATIONS

General Measurement
Number of Inputs: 3
Update Rate: up to 4 readings per second on display;
up to 14 readings per second with IEEE-488 interface
Measurement Modes: DC, RMS, Peak
Probe Compatibility: Standard, multi-axis, and custom probes
Probe Features: Linearity Correction, Temperature Correction,
Auto Probe Zero, Differential Reading, Vector Magnitude
Measurement Features: Auto Range, Max Hold,
Relative Mode, Filter
Probe Connector: 15 pin D style

DC Measurement
DC Display Resolution: 5¾ digits with filter,
4¾ digits without filter

Range	Resolution w/ Filter	Resolution w/out Filter
HST Probe		
300 kG	0.001 kG	0.01 kG
30 kG	0.0001 kG	0.001 kG
3 kG	0.00001 kG	0.0001 kG
300 G	0.001 G	0.01 G
HSE Probe		
30 kG	0.0001 kG	0.001 kG
3 kG	0.00001 kG	0.0001 kG
300 G	0.001 G	0.01 G
30 G	0.0001 G	0.001 G
UHS Probe		
30 G	0.0001 G	0.001 G
3 G	0.00001 G	0.0001 G
300 mG	0.001 mG	0.01 mG

DC Accuracy: ±0.10% of reading ±0.005% of range
DC Temperature Coefficient: ±0.05% of reading
±0.03% of range/°C

AC RMS & Peak Measurement
AC Display Resolution: 4¾ digits

Range	RMS Resolution	Peak Resolution
HST Probe		
300 kG	0.01 kG	0.01 kG
30 kG	0.001 kG	0.001 kG
3 kG	0.0001 kG	0.0001 kG
300 G	0.01 G	—
HSE Probe		
30 kG	0.001 kG	0.001 kG
3 kG	0.0001 kG	0.0001 kG
300 G	0.01 G	0.01 G
30 G	0.001 G	—
UHS Probe		
30 G	0.001 G	0.001 G
3 G	0.0001 G	0.0001 G
300 mG	0.01 mG	—

AC Frequency Range: 10 – 400 Hz
AC RMS Accuracy: ±2% of reading (50 – 60 Hz)
AC RMS Freq. Response: 0 to -3.5% of reading (10 – 400 Hz)
(All AC RMS specifications for sinusoidal input >1% of range)
AC Peak Accuracy: ±5% typical
AC Peak Speed: 5 ms for single peak

Front Panel
Display Type: 4 line by 20 character, vacuum fluorescent
Display Resolution: Up to ±5¾ digits
Display Update Rate: 4 rdgs/sec. Vector Off, 3 rdgs/sec On
Displays Units: Gauss (G), Tesla (T)
Units Multipliers: μ, m, k
Annunciators:

RMS	AC input signal
DC	DC input signal
MAX	Max Hold value
Δ	Relative reading
R	Remote operation
♪	Alarm on

Keypad: 25 full travel keys
Front Panel Features: Intuitive operation, display prompts,
front panel lockout, brightness control

Interfaces
RS-232C Capabilities:
Baud: 300, 1200, 9600
Connector: RJ-11 configuration
Update Rate: Up to 14 readings per second
IEEE-488 Capabilities:
Complies with IEEE-488.2: SH1 AH1 SR1 RL1 PP0 DC1 DT0 C0 E1
Software Support: LabView Driver
Update Rate: 18 rdgs/sec. Vector Off, 14 rdgs/sec. Vector On
Alarm:
Settings: High and low set point, Inside/Outside, Audible
Actuators: Display annunciator, beeper
Monitor Analog Output (3)
Configuration: Real-time analog voltage output
Scale: ±3 V = ±FS on selected range
Frequency Response: DC to 400 Hz
Accuracy: Probe dependent
Minimum Load Resistance: 1 kΩ (short circuit protected)
Connector: BNC
Corrected Analog Output (1)
Configuration: Voltage output generated by DAC
Range: ±3 V; ±10 V for Model 460-10
Scale: User defined
Resolution: 0.366 mV of ±3 V
Update Rate: Same as field measurement
Accuracy: ±0.1% of full scale in addition to measurement error
Minimum Load Resistance: 1 kΩ (short circuit protected)
Connector: BNC

General
Ambient Temperature: 15 – 35 °C at rated accuracy.
5 – 40 °C with reduced accuracy
Power Requirement: 100, 120, 220, 240 VAC (+5%, -10%),
50 or 60 Hz, 40 watts
Size: 434 W x 89 H x 369 mm D (17.1 x 3.5 x 14.5 in.), half rack
Weight: 7.5 kilograms (16.5 pounds)
Approval: CE Mark

Ordering Information
Part number *Description*

Instrument
460 Model 460 Gaussmeter, ±3 V corrected analog output
460-10 Model 460 Gaussmeter, ±10 V corrected analog output

Accessories Included
115-006 Detachable line cord (U.S.)
115-007 Detachable line cord (European)
4060 Zero gauss chamber
MAN-460 Model 460 Gaussmeter User's Manual

Accessories Available
4001 RJ-11 cable assembly
4002 RJ-11 to DB-25 adapter
4003 RJ-11 to DE-9 adapter
4004 IEEE-488 cable, 1 meter (3 feet)
4065 Large zero gauss chamber for Gamma probe
RM-1 Rack mount kit for one 460 gaussmeter
MCBL-6 User programmable cable with PROM (6' long)
MCBL-20 User programmable cable with PROM (20' long)
MPEC-10 Probe extension cable with EEPROM (10' long)
MPEC-25 Probe extension cable with EEPROM (25' long)
MPEC-50 Probe extension cable with EEPROM (50' long)
MPEC-100 Probe extension cable with EEPROM (100' long)
(Extension cables must be matched to probes)

Probes Ordered Separately
Custom Probes Available (Consult Lake Shore for more information)
Specifications are subject to change without notice.

1.3 SAFETY SUMMARY

Observe these general safety precautions during all phases of instrument operation, service, and repair. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended instrument use. Lake Shore Cryotronics, Inc. assumes no liability for Customer failure to comply with these requirements.

The Model 460 protects the operator and surrounding area from electric shock or burn, mechanical hazards, excessive temperature, and spread of fire from the instrument. Environmental conditions outside of the conditions below may pose a hazard to the operator and surrounding area.

- Temperature: 5 C° to 40 °C.
- Maximum relative humidity: 80% for temperature up to 31 °C decreasing linearly to 50% at 40 °C.
- Power supply voltage fluctuations not to exceed ±10% of the nominal voltage.

Ground The Instrument
To minimize shock hazard, connect the instrument chassis and cabinet to an electrical ground. The instrument is equipped with a three-conductor AC power cable. Plug the power cable into an approved three-contact electrical outlet or use a three-contact adapter with the grounding wire (green) firmly connected to an electrical ground (safety ground) at the power outlet. The power jack and mating plug of the power cable meet Underwriters Laboratories (UL) and International Electrotechnical Commission (IEC) safety standards.

Do Not Operate In An Explosive Atmosphere
Do not operate the instrument or probes in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment constitutes a definite safety hazard.

Keep Away From Live Circuits
Operating personnel must not remove instrument covers. Refer component replacement and internal adjustments to qualified maintenance personnel. Do not replace components with power cable connected. To avoid injuries, always disconnect power and discharge circuits before touching them.

Do Not Substitute Parts Or Modify Instrument
Do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to an authorized Lake Shore Cryotronics, Inc. representative for service and repair to ensure that safety features are maintained.

1.4 SAFETY SYMBOLS

Direct current (power line).

Alternating current (power line).

Alternating or direct current (power line).

Three-phase alternating current (power line).

Earth (ground) terminal.

Protective conductor terminal.

Frame or chassis terminal.

On (supply)

Off (supply)

Equipment protected throughout by double insulation or reinforced insulation (equivalent to Class II of IEC 536 - see Annex H).

Caution: High voltages; danger of electric shock. Background color: Yellow; Symbol and outline: Black.

Caution or Warning - See instrument documentation. Background color: Yellow; Symbol and outline: Black.

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CHAPTER 2

INSTALLATION

2.0 GENERAL

This chapter provides general Model 460 installation instructions: inspection and unpacking in Paragraph 2.1, repackaging for shipment in Paragraph 2.2, definition of rear panel connections in Paragraph 2.3, and initial setup and system checkout procedure in Paragraph 2.4.

2.1 INSPECTION AND UNPACKING

Inspect shipping containers for external damage. Make all claims for damage (apparent or concealed) or partial loss of shipment in writing to Lake Shore within five (5) days from receipt of goods. If damage or loss is apparent, please notify the shipping agent immediately.

Open the shipping containers. Use the packing list included with the system to verify receipt of the instrument, probes, accessories, and manual. Inspect for damage. Inventory all components supplied before discarding any shipping materials. If there is freight damage to the instrument, file proper claims promptly with the carrier and insurance company and notify Lake Shore. Notify Lake Shore immediately of any missing parts. Lake Shore cannot be responsible for any missing parts unless notified within 60 days of shipment. Refer to the standard Lake Shore Warranty on the A Page (behind the title page).

2.2 REPACKAGING FOR SHIPMENT

If it is necessary to return the Model 460, probe(s), or accessories for repair or replacement, a Return Goods Authorization (RGA) number must be obtained from a factory representative before returning the instrument to our service department. When returning an instrument for service, the following information must be provided before Lake Shore can attempt any repair.

1. Instrument model and serial number.
2. User's name, company, address, and phone number.
3. Malfunction symptoms.
4. Description of system.
5. Returned Goods Authorization (RGA) number.

If possible, the original packing material should be retained for reshipment. If not available, consult Lake Shore for shipping and packing instructions.

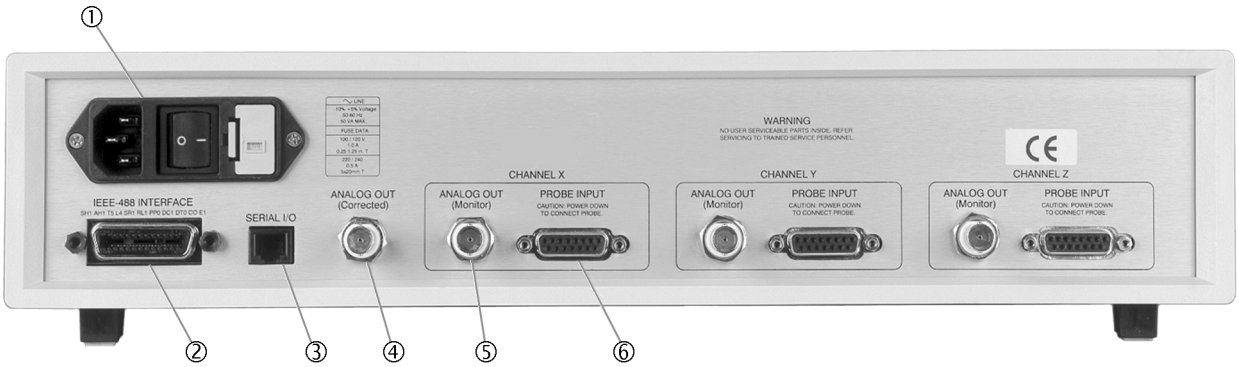
Because of their fragility, Lake Shore probes are shipped in special cardboard and foam boxes. These boxes should be retained for storage of probes while the gaussmeter is not in use. The same box can be used to return probes to Lake Shore for recalibration or repair.

2.3 REAR PANEL DEFINITION

This paragraph provides a description of the Model 460 rear panel connections. The rear panel consists of the line input assembly, IEEE-488 Interface Connector, Serial I/O Connector, Probe Input Connectors, and Corrected and Monitor Analog Output BNCs. This paragraph is provided for information only. Please read the entire paragraph then proceed to Paragraph 2.7 for the initial setup and system checkout procedure. Rear panel connector pin-out details are provided in Chapter 6 – Service.

CAUTION: Verify AC Line Voltage shown in the fuse holder window is appropriate for the intended AC power input. Also remove and verify the proper fuse is installed before plugging in and turning on the instrument.

CAUTION: Always turn off the instrument before making any rear panel connections. This is especially critical when making probe to instrument connections.



460_Back.bmp

		Description	*Pin Definition*
①	Line Input Assembly	Paragraph 2.4	Figure 2-2
②	IEEE-488 INTERFACE Connector	Paragraph 6.5.1	Figure 6-5
③	SERIAL I/O RJ-11 Connector	Paragraph 4.2.1	Figure 6-4
④	ANALOG OUT Corrected BNC	Paragraph 2.6 and 3.13.1	Figure 6-3
⑤	ANALOG OUT Monitor BNC (Quantity 3)	Paragraph 2.6 and 3.13.2	Figure 6-3
⑥	PROBE INPUT 15 pin D-Style Connector (Quantity 3)	Paragraph 2.5	Figure 6-2

Figure 2-1. Model 460 Rear Panel

2.4 LINE INPUT ASSEMBLY

This section covers line voltage and fuse verification in Paragraph 2.4.1, power cord in Paragraph 2.4.2, and power switch in Paragraph 2.4.3.

2.4.1 Line Voltage and Fuse Verification

To verify proper line voltage selection look at the indicator in the window on the fuse drawer of the line input assembly. Line voltage should be in the range shown in the specifications listed on the back of the instrument. See Figure 2-2. If not, change the line voltage selector per instructions in Paragraph 6.3. The fuse must be removed to verify its value, refer to the procedure in Paragraph 6.4. Use slow-blow fuses of the value specified on back of the instrument.

2.4.2 Power Cord

The Model 460 includes a three-conductor power cord. Line voltage is present across the outer two conductors. The center conductor is a safety ground and connects to the instrument metal chassis. For safety, plug the cord into a properly grounded three-pronged receptacle.

2.4.3 Power Switch

The power switch turns the instrument On and Off and is located in the line input assembly on the instrument rear. When **I** is raised, the instrument is On. When **O** is raised, the instrument is Off.

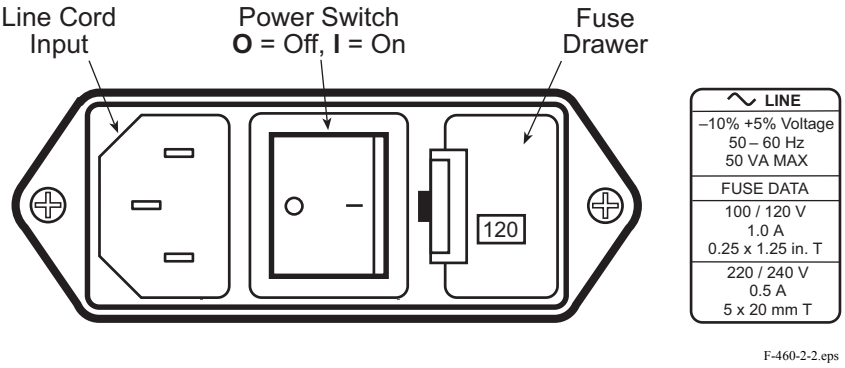


Figure 2-2. Line Input Assembly

2.5 PROBE INPUT CONNECTION

WARNING: Some probes used with the gaussmeter have conductive parts. Never probe near exposed live voltage. Personal injury and damage to the instrument may result.

CAUTION: Always turn off the instrument before making any rear panel Probe Input connections.

Lake Shore probes plug into three 15 pin D-style connectors on the rear panel. Turn the instrument off before attaching a probe. Align the probe connector with the rear panel connector and push straight in to avoid bending the pins. For best results, secure the connector to the rear panel using the two thumbscrews. A tight connector keeps the cable secure and prevents interference.

To use a 2 or 3-Axis probe, X, Y, and Z probes must be connected to their respective rear panel connectors. On multi-axis probes, each connector is marked with a channel (axis) designation. The Y and Z probes will not function if the X channel is turned off or the X connector is removed. Refer to Paragraph 3.17 for additional probe considerations.

When power is turned on, the instrument reads parameters from probe memory. The probe is ready to use. No parameters need to be entered into the Model 460. However, the Zero Probe function should be performed the first time a probe is used with the instrument and periodically during use.

2.5.1 Attachment To A Hall Generator

The Model MCBL-XX has a 15 pin D-Style connector on one end for direct attachment to any of the PROBE INPUT connections on the back panel of the Model 460 Gaussmeter. Four tinned wires are provided for connection to the Hall Generator. The leads may be soldered directly to these wires. The cable comes in two lengths: the MCBL-6 is 2 meters (6 feet) and the MCBL-20 is 6 meters (20 feet).

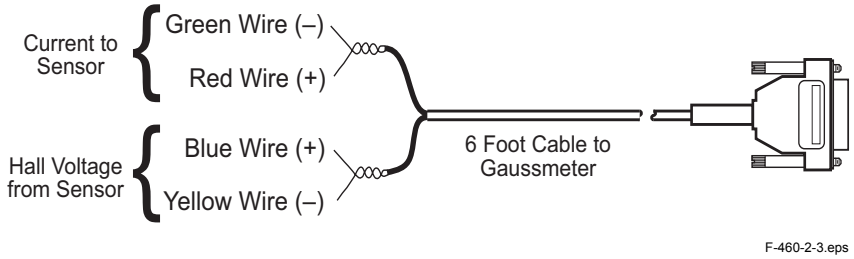


Figure 2-3. Model MCBL-XX User Programmable Cable Accessory

CAUTION: The Hall Generator should be isolated from all line voltages (or voltages referenced to earth ground). *If not, damage to the Model 460 Gaussmeter is almost a certainty.*

Refer to Appendix C for a complete list of compatible Hall generators manufactured by Lake Shore. Once connections are made, refer to Paragraph C6.0 for instructions on using the Hallcall.exe program to store probe parameters in the internal EPROM.

2.6 CORRECTED AND MONITOR ANALOG OUTPUTS

Analog outputs are available on Bayonet Nut Connectors (BNCs). The signal is on the center conductor while the outer casing is for ground. All outputs may be used simultaneously. The corrected output is not a real-time signal, but is updated at the same rate as the display. The monitor outputs are live analog signals proportional to the magnetic flux density waveform of the respective channel. Refer to Paragraph 3.13 for further operational information.

2.7 INITIAL SETUP AND SYSTEM CHECKOUT PROCEDURE

This procedure verifies basic unit operation before initial use for measurements.

CAUTION: Check power source for proper voltage before connecting line cord to the Model 460. Check power setting on fuse drawer window. Damage may occur if connected to improper voltage.

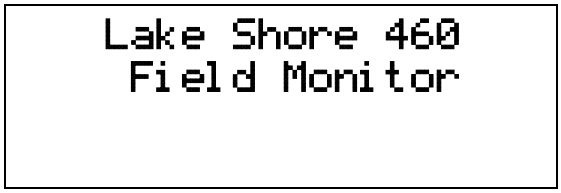
1. Check power source for proper voltage. The Model 460 operates with 100, 120, 220, or 240 (+5%, –10%) AC input voltage. If incorrect, refer to Paragraph 6.3.
2. Check fuse drawer window for proper voltage setting. If incorrect, refer to Paragraph 6.4.
3. Ensure power switch is off (**O**).

CAUTION: The probe must be connected to the rear of the unit before applying power to the gaussmeter. Damage to the probe may occur if connected with power on.

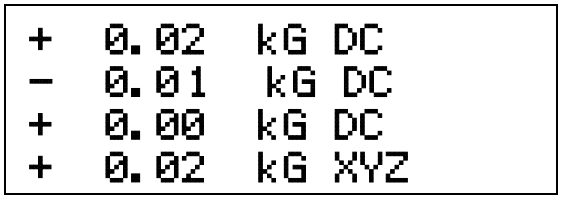
4. Plug in the DA-15 probe connector to PROBE INPUT. Use thumbscrews to tighten connector to unit.
5. Connect and check all other rear panel connections (ANALOG OUTPUTS and IEEE-488 or SERIAL I/O) before applying power to the unit.
6. Plug line cord into receptacle.

Initial Setup And System Checkout Procedure (Continued)

7. Turn power switch on (**I**). The front panel display turns on and briefly displays the following message.



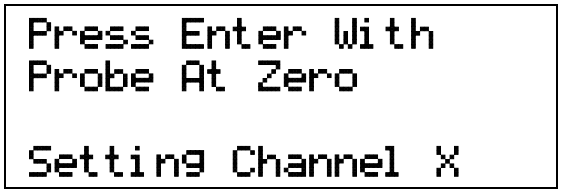
8. The normal gaussmeter display appears (similar to below).



NOTE: For best results, the instrument and probe should warm up for at least 5 minutes before zeroing the probe, and at least 30 minutes for rated accuracy. The probe and the zero gauss chamber should be at the same temperature.

NOTE: Some Lake Shore probes come with a clear plastic sleeve to protect the probe tip when not in use. The sleeve slides up and down the probe cable. To place the probe in the zero gauss chamber, slide the protective sleeve back, exposing the probe tip, before placing the tip in the chamber.

9. Place the probe in the zero gauss chamber. Once inserted, press the **Channel** key (in this case, Channel X), then press the **Zero Probe** key. You will see the following display.



10. Press the **Enter** key. The ***CALIBRATING*** message briefly displays, followed by the normal display. Do not move the probe while the ***CALIBRATING*** message displays. There should be a near-zero reading on the display when finished.

11. Repeat Steps 9 and 10 for the Y and Z probes, if present.

NOTE: If the unit has performed well to this point, the unit is functioning properly. If you have a reference magnet available, you can continue with the test using the magnet to verify the accuracy of the Model 460.

Initial Setup And System Checkout Procedure (Continued)

12. If continuing the procedure with a reference magnet, ensure the probe can accommodate the range of the magnet. Use the **Range** key to select the proper range. Set the display for DC. Finally, since orientation of the probe is very selective, press the **Max Hold** key. This will capture the highest reading (normally the reference magnet calibration value).

CAUTION: Care must be exercised when handling the probe. The tip of the probe is very fragile. Any excess force may break the probe.

NOTE: Probe readings are dependent upon the angle of the tip in relation to the magnetic field. (This does not apply to 3-axis probes.) This and other effects on probe operation are explained in Paragraph 3.17.

13. Carefully place probe into reference magnet. You may have to hunt around for the maximum reading. For this example, we are using a 999 ±1% Gauss Reference Magnet. Our reading appeared as follows:

Assuming we are using a probe attached to the X axis, the maximum reading captured was 0.9950 kG, which is within the tolerance of the reference magnet. The reading will change as the probe moves around, but will eventually remain fixed on the highest reading. To recapture a new maximum value, press the **Max Reset** key.

14. Repeat Steps 12 and 13 for the Y and Z probes, if present.

15. Once this abbreviated checkout procedure is successfully completed, the unit is ready for normal operation. Please proceed to Chapter 3 for further operational information.

CHAPTER 3
OPERATION

3.0 GENERAL

This chapter describes Model 460 3-Channel Gaussmeter operation. The front panel controls are described in Paragraph 3.1. Paragraphs 3.2 thru 3.14 describe the various front panel functions in detail. Model 460 default settings are defined in Paragraph 3.15. Special functions available over computer interface are discussed in Paragraph 3.16. Finally, probe considerations are presented in Paragraph 3.17. Refer to Chapter 4 for information on remote operation (via IEEE-488/Serial).

3.1 DEFINITION OF FRONT PANEL CONTROLS

This paragraph provides a description of the front panel controls on the Model 460. The front panel consists of two major sections: a description of the 25 front panel keys in Paragraph 3.1.1, and a description of the front panel display in Paragraph 3.1.2. Front panel navigation is described in Paragraph 3.1.3. Turning channels on and off is described in Paragraph 3.1.5. Finally, the various Vector Magnitude settings are described in Paragraph 3.1.5.

3.1.1 Front Panel Keypad Definitions

The keys on the front panel are defined as follows. Note the following are abbreviated descriptions of each key. A more detailed description of each function is provided in subsequent paragraphs.

X Selects Channel X. Once pressed, selection of any subsequent channel specific functions (relative, alarm, range, etc.) will affect Channel X. Press and hold to turn the channel off. Refer to Paragraph 3.1.3.

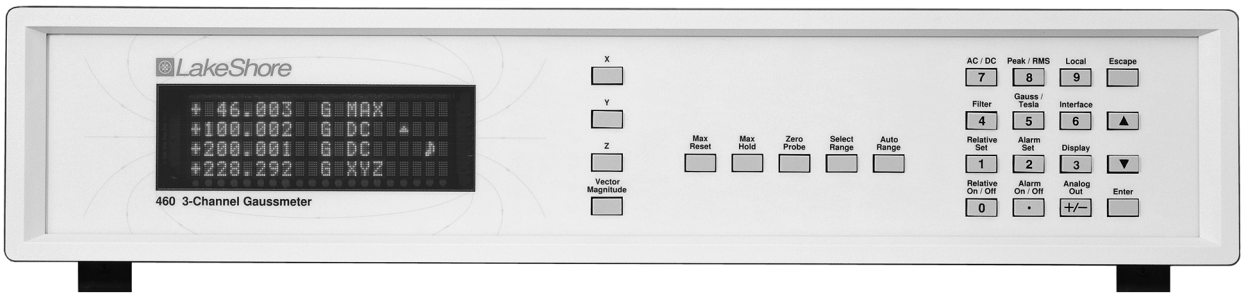
Y Selects Channel Y. Once pressed, selection of any subsequent channel specific functions will affect Channel Y. Press and hold to turn the channel off. Refer to Paragraph 3.1.3.

Z Selects Channel Z. Once pressed, selection of any subsequent channel specific functions will affect Channel Z. Press and hold to turn the channel off. Refer to Paragraph 3.1.3.

Vector Magnitude Selects Vector Magnitude. Once pressed, selection of any subsequent specific functions will affect the Vector Magnitude. Press and hold to set the vector source. Refer to Paragraphs 3.1.3 and 3.1.4.

Max Reset Works with the Max Hold function. Clears Max reading back to normal field reading. Refer to Paragraph 3.2.

Max Hold Turns Max Hold feature on or off. Max Hold captures and displays the highest field reading. Use Max Reset key to clear reading. Refer to Paragraph 3.2.



460_Front.bmp

Figure 3-1. Model 460 Front Panel

Front Panel Keypad Definitions (Continued)

Zero Probe Used to zero or null effects of ambient low level fields from the probe. This function is not available for Vector Magnitude. Refer to Paragraph 3.3.

Select Range Push to manually select the field measurement range. Available ranges are dependent on which probe is installed. This function is not available for Vector Magnitude. Refer to Paragraph 3.4.

Auto Range Turns the Auto Range feature on and off. Allows the Model 460 to automatically select the field measurement range. This function is not available for Vector Magnitude. Refer to Paragraph 3.4.

AC/DC Selects periodic (AC) or static (DC) magnetic fields. The AC selection provides the user with the choice of Peak or RMS readings. This function is not available for Vector Magnitude. Refer to Paragraph 3.5.

Peak/RMS The AC selection provides the user with the choice of Peak or Root Mean Square (RMS) readings. AC peak can also be used with the Max Hold feature to measure single pulse peak values. This function is not available for Vector Magnitude. Refer to Paragraph 3.5.

Filter Turns the filter on or off and allows configuration of filter. Filter on enables high resolution DC readings. Press and hold Filter key to select Field Compensation and Temperature Compensation on or off. This function is not available for Vector Magnitude. Refer to Paragraph 3.6.

Gauss/Tesla Changes display units from gauss to tesla. Gauss (G) is used in the cgs system, where 1 G = 10^{-4} T. Tesla (T) is used in the SI system, where 1 T = 10^{4} G. This is a global setting (applies to all channels). Refer to Paragraph 3.8.

Relative Set With the relative feature turned on, this key is used to capture the present field reading as the relative setpoint. You also have the option of entering a number via the numerical keypad. Works with the Relative On/Off key. Refer to Paragraph 3.9.

Relative On/Off Turns on the relative feature which displays the positive or negative deviation from the relative setpoint. The relative feature can also be used with the Max Hold and Alarm features. Refer to Paragraph 3.9.

Alarm Set This key is used to set the high and low alarm points. The alarm setpoints are absolute (unsigned) i.e., the positive or negative aspect of the field reading is ignored. Refer to Paragraph 3.10.

Alarm On/Off Turns the alarm feature on or off. Press and hold the Alarm On/Off key to turn the audible alarm on or off and select the alarm to activate inside or outside the range. Refer to Paragraph 3.10.

Local This key is used to select local or remote operation. When set to Local, the unit responds to front panel controls. When set to Remote, the unit is controlled via the IEEE-488 Interface. Refer to Paragraph 3.11.

Interface Sets the bus address and terminators for the IEEE-488 Interface and Baud rate for the Serial Interface. Refer to Paragraph 3.11.

Display Use this key to set the display brightness. Refer to Paragraph 3.12.

Analog Out Used to set the source and scaling of the Corrected Analog Output. The scaling of the three Monitor Analog Outputs cannot be modified. Refer to Paragraph 3.13.

Front Panel Keypad Definitions (Continued)

Escape	Terminates a function without making changes to the existing settings. Press and hold the Escape key for ≈20 seconds to reset the instrument and return parameters to factory default values. Refer to Paragraph 3.15.
▲	The up triangle (▲) serves two functions. The first is to toggle between various settings shown in the display. The second is to increment a numerical display.
▼	The down triangle (▼) serves two functions. The first is to toggle between various settings shown in the display. The second is to decrement a numerical display.
Enter	The Enter key is used to accept changes made in the field display. Press and hold the Enter key to gain access to the Keypad Lock display. A 3-digit code may be entered to lockout the keypad from accepting changes. Refer to Paragraph 3.14.

3.1.2 Front Panel Display

In normal operation, the four row by twenty character vacuum fluorescent display provides readings for Channel X on the first line, Channel Y on the second line, Channel Z on the third line, and Vector Magnitude (if selected) on the fourth line of the display. Other information is displayed when using the various functions on the keypad. Each character is comprised of a 5 by 7 dot matrix. Note the extra digit on the display will only appear if the channel is in DC mode and the Filter is turned on. See Figure 3-2.

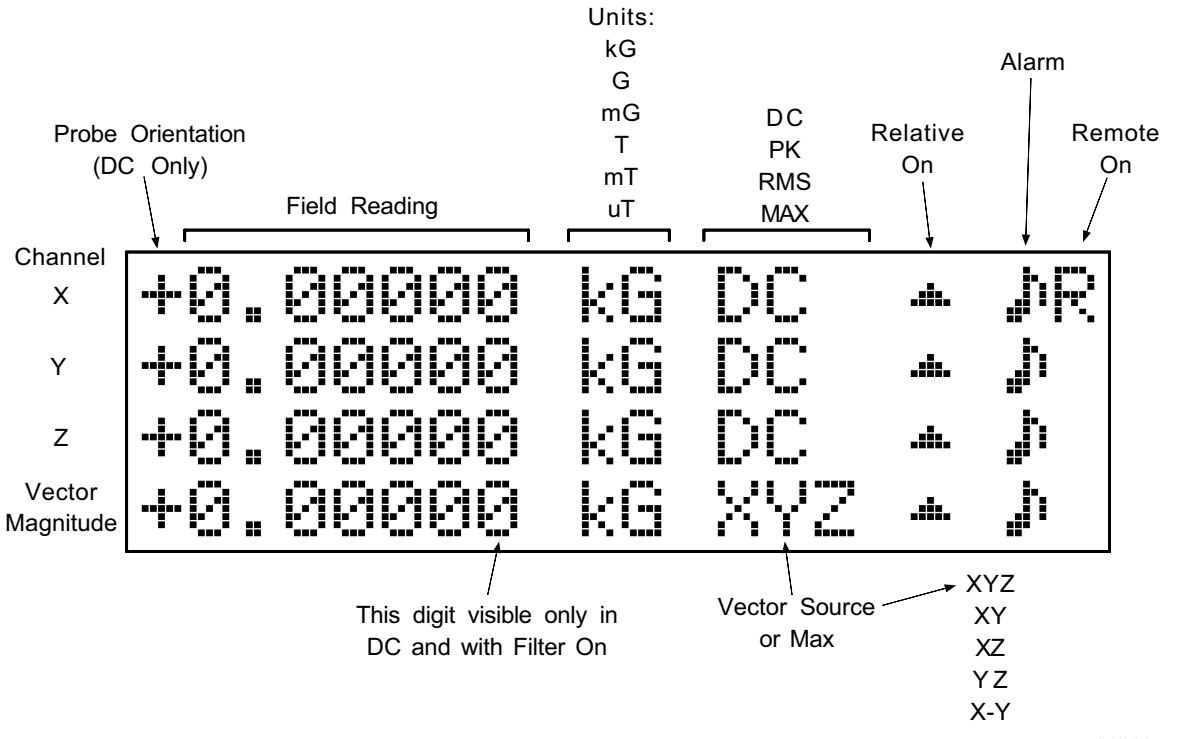


Figure 3-2. Front Panel Display Definition

3.1.3 Front Panel Navigation

Information in the first line of the display pertains to Channel X, the second line to Channel Y, third line to Channel Z, and the fourth line to the Vector Magnitude. To select a function for a channel, you must first push the **X**, **Y**, **Z**, or **Vector Magnitude** key. Once selected, all subsequent channel specific operations will affect that channel until another channel key is pressed.

The following is an example of how channel selection works. If you want to turn Max Hold on for Channel X, you must first press the Channel **X** key. You will briefly see the following display.

```
Setting Channel X
-0.26776 kG DC
-0.90952 kG DC
-0.95325 kG XYZ
```

You may then press the **Max Hold** key. You will see the following display. (The Max Hold function is described in detail in Paragraph 3.2).

```
Max Hold ON
-0.26776 kG DC
-0.90952 kG DC
+0.95325 kG XYZ
```

In fact, you may press any number of applicable functions and they all will affect Channel X. This will continue until another channel or the **Vector Magnitude** key is pressed, or the unit is turned off (in which case, it will default back to Channel X).

After a short timeout, the X channel display will return to normal, with the Max Hold value being displayed on the first line as seen in the following display.

```
-0.09228  kG MAX
-0.26776  kG DC
-0.90952  kG DC
+0.95260  kG DC
```

3.1.4 Channel On/Off

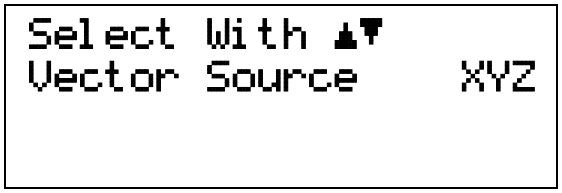
Each channel may be independently turned on or off. To do this, press and hold the **X**, **Y**, **Z**, or **Vector Magnitude** key. For example, if we wanted to turn Channel X on, we would press and hold the Channel **X** key. You will see the following display.

```
Select With ▲▼
Channel     →On   Off

Setting Channel X
```

Use the ▲ or ▼ arrow keys to toggle the channel on or off. Press the **Enter** key to select a new setting, or press the **Escape** key (or wait for the time out) to exit and retain the old setting. If the channel is turned off, the line in the display will be blank (and the excitation current will be turned off to the X, Y, or Z channels). Do no turn off the X-channel when using a multi-axis probe. If no probe is attached to a channel, the corresponding display will be blank (regardless if the channel is turned on or off).

3.1.5 Vector Source

In addition to turning the Vector Magnitude display on or off, the source of the Vector display must also be selected. Press and hold the **Vector Magnitude** key until the display reads Channel ON, then press the **Enter** key. You will see the following display.



Use the ▲ or ▼ arrow keys to toggle the vector source between XYZ, XY, XZ, YZ, and X–Y. Press the **Enter** key to select a new setting, or press the **Escape** key (or wait for the timeout) to exit and retain the old setting. The vector source will be shown in the normal display. However, if Max Hold is selected for the vector magnitude display, the identifier MAX will appear in the normal display instead of the vector source.

The following is a mathematical description of the components that comprise the Vector Magnitude source.

$$XYZ=\sqrt{X_{Reading}{}^2+Y_{Reading}{}^2+Z_{Reading}{}^2} \quad \text{(Full 3-axis)}$$

$$XY=\sqrt{X_{Reading}{}^2+Y_{Reading}{}^2} \quad \text{(In the X-Y plane)}$$

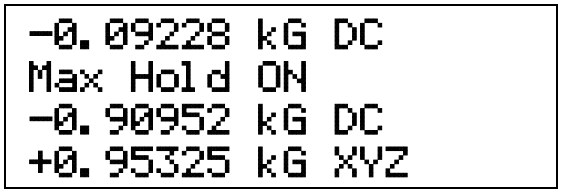
$$XZ=\sqrt{X_{Reading}{}^2+Z_{Reading}{}^2} \quad \text{(In the X-Z plane)}$$

$$YZ=\sqrt{Y_{Reading}{}^2+Z_{Reading}{}^2} \quad \text{(In the Y-Z plane)}$$

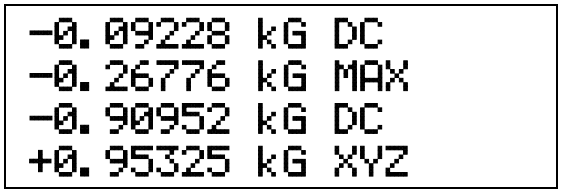
$$X\text{-}Y=X_{Reading}-Y_{Reading} \quad \text{(Differential)}$$

3.2 MAX HOLD AND MAX RESET

The Max Hold function displays the largest field magnitude measured since the last Max Reset. When the **Max Hold** key is pressed, the currently selected channel will change to display the MAX reading. For example, to turn Max Hold on for Channel Y, press the Channel **Y** key, followed by the **Max Hold** key. You will see the following display.



After a short timeout, the Y channel display will return to normal, with the Max hold value being displayed on the second line of the display as seen in the following display.



Max Hold and Max Reset (Continued)

The **Max Reset** key clears the Max Hold value. The Max Hold value is also reset upon power up or when changing from AC or DC. Max Hold may also be used in conjunction with the Relative display (refer to Paragraph 3.9). Max Hold functions differently when being used with AC or DC fields as follows.

In DC operation, the Max Hold feature holds the field reading that is largest in magnitude. This is intended to monitor slowly changing signals. A field change not visible on the display can not be recorded in DC Max Hold. The display shows only the magnitude of the maximum reading.

In AC RMS operation, the maximum RMS value displayed is held, i.e., operates the same as DC Max. In AC Peak operation, a hardware circuit traps peaks in the Hall voltage. In this mode, the unit displays the magnitude of the highest peak of an impulse or event. For best accuracy, the event must be at full amplitude for at least a few milliseconds.

In the case of the Vector Magnitude display, turning on Max Hold will cause the vector source display to be replaced with MAX. Turning on Max Hold for Vector Magnitude means the maximum value calculated will be displayed. It does not mean each of the individual component max hold readings are used to form the Vector Magnitude display. When Max Hold for the Vector Magnitude is turned off, but Max Hold for the X, Y, or Z channels is on, the individual maximums are for display only and are not used for the calculation of the Vector Magnitude display.

3.3 ZERO PROBE

The zero probe function is used to null (cancel) out the zero offset of the probe or small magnetic fields. It is normally used in conjunction with the zero gauss chamber, but may also be used with an unshielded probe (registering the local earth magnetic field). If three separate probes are being used, each probe may be independently zeroed. For the three-axis probes, each axis may be independently zeroed. Users wishing to cancel large magnetic fields must use the Relative function. The zero probe function is not available for the Vector Magnitude display.

NOTE: For best results, the instrument and probe should warm up for at least 5 minutes before zeroing the probe, and at least 30 minutes for rated accuracy. The probe and the zero gauss chamber should be at the same temperature.

NOTE: Some Lake Shore probes are equipped with a clear plastic sleeve intended to protect the tip of the probe when not being used. The sleeve is designed to slide up and down the probe cable. If you need to place the probe in the zero gauss chamber, you must slide the protective sleeve back, exposing the tip of the probe, before placing the tip in the chamber.

To zero the probe in the zero gauss chamber, first allow the temperature of the probe and chamber to equalize. (A large temperature discrepancy affects the quality of the calibration.) Carefully place the probe tip into the chamber. Orientation of the probe is not critical. Once inserted, press the channel key (in this case, Channel X), then press the **Zero Probe** key and observe the following display.

```
Press Enter With
Probe At Zero

Setting Channel X
```

Press the **Enter** key. The ***CALIBRATING*** message is displayed, followed by a return to the normal display. Do not move the probe while calibrating. The probe is now zeroed. For best results, periodic zeroing of the probe is recommended.

3.4 SELECT RANGE AND AUTO RANGE

Each channel of the Model 460 is capable of reading any of the Lake Shore probe types: High Stability, High Sensitivity, or Ultra-High Sensitivity. The three probes permit the Model 460 to sense fields as low as 0.01 mG and as high as 300 kG. The full scale ranges for each probe sensitivity, along with the fixed display resolution, are shown in the following tables.

The range for the Vector Magnitude display is not directly settable. Instead, Vector Magnitude will display the same resolution as the highest range setting of the component channels. For example, if the Vector Magnitude is set for XYZ, and all three channels are in the ±3 kG range, the Vector Magnitude range will also be ±3 kG. If one of the channels is switched to ±30 kG (does not matter which one), the Vector Magnitude range will also switch to ±30 kG.

High Stability Probe (HST)

Gauss			Tesla		
Range	Resolution		Range	Resolution	
	AC, or DC with Filter Off	DC Filter On		AC, or DC with Filter Off	DC Filter On
±300 kG	±0.01 kG	±0.001 kG	±30 T	±0.001 T	±0.0001 T
±30 kG	±0.001 kG	±0.0001 kG	±3 T	±0.0001 T	±0.00001 T
±3 kG	±0.0001 kG	±0.00001 kG	±300 mT	±0.01 mT	±0.001 mT
±300 G	±0.01 G	±0.001 G	±30 mT	±0.001 mT	±0.0001 mT

High Sensitivity Probe (HSE)

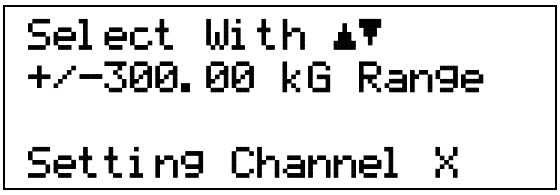
Gauss			Tesla		
Range	Resolution		Range	Resolution	
	AC, or DC with Filter Off	DC Filter On		AC, or DC with Filter Off	DC Filter On
±30 kG	±0.001 kG	±0.0001 kG	±3 T	±0.0001 T	±0.00001 T
±3 kG	±0.0001 kG	±0.00001 kG	±300 mT	±0.01 mT	±0.001 mT
±300 G	±0.01 G	±0.001 G	±30 mT	±0.001 mT	±0.0001 mT
±30 G	±0.001 G	±0.0001 G	±3 mT	±0.0001 mT	±0.00001 mT

Ultra-High Sensitivity Probe (UHS)

Gauss			Tesla		
Range	Resolution		Range	Resolution	
	AC, or DC with Filter Off	DC Filter On		AC, or DC with Filter Off	DC Filter On
±30 G	±0.001 G	±0.0001 G	±3 mT	±0.0001 mT	±0.00001 mT
±3 G	±0.0001 G	±0.00001 G	±300 µT	±0.01 µT	±0.001 µT
±300 mG	±0.01 mG	±0.001 mG	±30 µT	±0.001 µT	±0.0001 µT

Select Range and Auto Range (Continued)

For manual ranging, first press the desired channel, in this case, press the channel **X** key. Then press the **Select Range** key. This allows the user to see the full scale value for the present range as follows.



Press the **Select Range** or ▲ or ▼ keys to cycle through the allowable full scale ranges for the probe installed. Use the **Enter** key to accept the new range or **Escape** key to retain the old range. Changing ranges in this way disables the Auto Range function until Auto Range is turned on.

NOTE: When operating in AC Peak Mode only, you cannot select the lowest range for the probe installed. This is true for both Manual and Auto Range.

NOTE: If a range is manually selected that is too small for the reading, the reading will disappear and the letters "OL" (for over load) will be displayed. If displaying the Vector reading, any channel displaying OL will also cause the Vector display to display OL.

In Auto Range mode, the Model 460 selects the range with the best resolution for the field being measured. It can take up to 2 seconds for Auto Range to work, so manual ranging may be better in some conditions. Pressing the **Auto Range** key shows the following display.

Pressing the **Auto Range** or ▲ or ▼ keys cycles between On and Off. Push the **Enter** key to accept the new setting or the **Escape** key to leave the setting as is and return to the normal display.

Auto Ranging should not be used with Peak and Max Hold operation. Also, Auto Ranging should not be used when measuring small fields in a large background field, i.e., measuring a small DC field in presence of a large AC field, or measuring a small AC field in the presence of a large DC field.

3.5 AC/DC AND PEAK/RMS

After pressing the channel key, pressing the **AC/DC** key toggles between AC and DC measurements for that channel. The annunciator immediately changes from "DC" to "PK" or "RMS," as applicable. However, one update cycle is required for a new display value. The Model 460 updates the field reading several times per second. Please note that for the Vector Magnitude display to be logical, each of the component channels must have the same AC/RMS/Peak settings. If they are not, the Vector display will show "Component Mismatch." However, even when the "Component Mismatch" message is being displayed, the X, Y, and Z channel readings are still individually correct.

In DC operation, the display shows the DC field at the probe with sign (orientation) followed by the appropriate field units, the letters DC, displaying 4¾ digits with no filter or 5¾ digits with the Filter on. The DC value is available over the IEEE-488 and Serial Interfaces and both Analog Outputs.

AC/DC and Peak/RMS (Continued)

In AC operation, the user must select either RMS or Peak. Both meet specified accuracy from 10 to 400 Hz. The lowest range for the type probe installed is not available in the AC Peak mode. The AC RMS reading is a measurement of true RMS, defined as the square root of the average of the square of the field function taken through one period. The RMS reading will work on complex waveforms to a crest factor of 7 and DC component will be rejected if it is not large enough to overload the selected range.

The AC Peak readings can be used in two different applications. With Max Hold off, the Peak (Crest) of a periodic, symmetrical waveform is measured. If the field change at the probe is not well behaved, the peak reading will not always show the largest field value. In this case, look at the monitor output with an oscilloscope to see how the reading relates to the field. The Peak reading used with Max Hold on will measure the amplitude of a single peak like a magnetizing pulse. It will hold the reading until reset with Max Reset.

The AC value is available over the IEEE-488 and Serial Interfaces. A DC voltage representation of the Peak or RMS display reading is available from the Corrected Analog Output, while a true analog waveform is available from the Monitor Analog Outputs. (In fact, the Monitor Analog Outputs are not affected by the selection of AC or DC.)

When changing to AC or DC, previously established Relative and Alarm setpoints are maintained, but Max Hold operation changes. Refer to Paragraph 3.2 for details of Max Hold operation.

3.6 FILTER

The **Filter** key is used to initiate the display filter function. The display filter function is used to quiet the display and make it more readable when the probe is exposed to a noisy field. The display filter can be turned on or off independently for each probe channel. The filter does not apply directly to the Vector display, but the Vector computation will use the filtered computation values and the filtering of the components can greatly enhance the stability of the Vector reading.

Care should be taken when using the filter on changing fields because it may level off peaks and slow the response of the instrument. The filter function of the Model 460 is user configurable so that desired field changes can be seen and noise blocked. The filter also acts to quiet noise within the instrument, making an additional digit of usable resolution available with the filter on in DC.

To turn on the display filter, first press the desired channel, in this case, press the channel **Y** key. Then press the **Filter** key and observe the following display.

```
Select With ▲▼
Filter       →On
Off

Setting Channel  Y
```

Pressing the **Filter** or ▲ or ▼ keys toggles between On and Off. Press the **Enter** key to accept the new setting or the **Escape** key to leave the setting as is and return to the normal display.

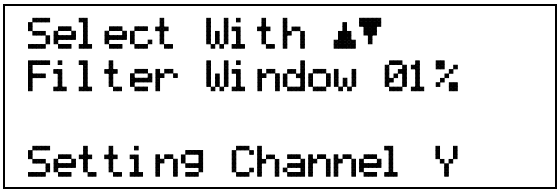
When the Filter is turned on, the user will see two additional displays. The first is the Filter Points display and the second is the Filter Window display. The default is 8 filter points and a 1% filter window. The Filter Points display is shown below.

```
Select With ▲▼
Filter Points 08

Setting Channel  Y
```

Filter (Continued)

The filter points tell the instrument how many points to use in the filter algorithm. From 2 to 64 points are permitted. One point is taken each display update cycle so the filter settling time will depend on update speed and number of samples.

The second display is for filter window as shown below.



The filter limit window sets a boundary for restarting the filter. If a single field reading is different from the filter value by more than the limit specified, the instrument will assume the change is intentional and restart the filter at the new reading value. This allows the instrument to respond to changing fields much faster than if the filter functioned continually. Filter Window can be set from 1% to 10% of the present range.

The Model 460 uses two different filter algorithms that result in slightly different settling time computations. For filter points from 2 to 8, a linear average is used to get the fastest possible response. In this case, the filter will settle in the same number of samples as entered. For example, when set at 8 filter points and updating at 4 readings per second, the filter will settle in 2 seconds.

For filter points from 9 to 64, an exponential algorithm is used to get a smooth response. The settling time for a 1% change to full display resolution is approximately the same as the number of filter points in seconds. For example, a setting of 10 filter points will settle in ≈10 seconds. The difference in linear and exponential response is illustrated in Figure 3-3.

The Vector Magnitude display uses filtered component values if in DC mode and the Filter is turned on for each of the component channels is turned on.

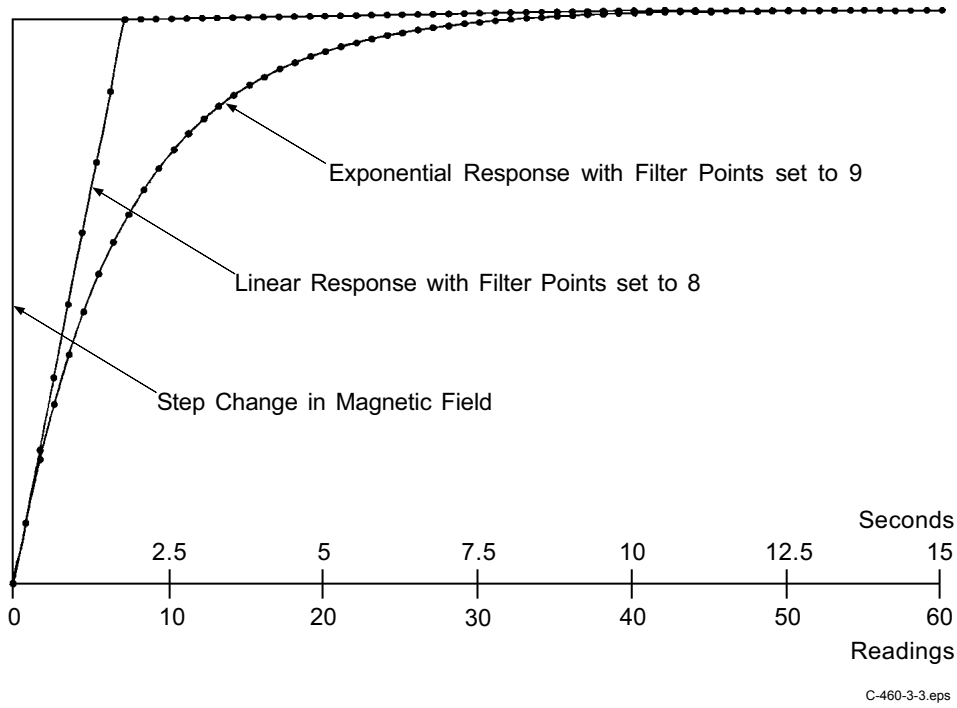


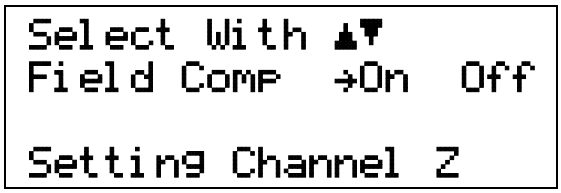
Figure 3-3. Display Filter Response Examples

3.7 FIELD AND TEMPERATURE COMPENSATION

Pressing and holding the **Filter** key for ≈5 seconds will show the following field and temperature compensation displays.

NOTE: Unless there is a specific reason to the contrary, Lake Shore strongly advises customers not to turn the field and temperature compensation off. The reading accuracy can be substantially reduced with the Field Compensation turned off.

Field and Temperature Compensation may be disabled by the user by selecting channel, then pressing and holding the **Filter** key for ≈5 seconds. After pressing and holding the **Filter** key for ≈5 seconds, the following Field Compensation display will appear.



To improve accuracy, many probes have a magnetic field compensation table stored in a PROM. Selecting Field Compensation Off will cause the Model 460 to ignore this table. Pressing the ▲ or ▼ keys cycles between On and Off. Push the **Enter** key to accept the new setting or the **Escape** key to leave the setting as is and return to the normal display. If the probe does not have field compensation, the setting is ignored.

Some probes also feature temperature compensation. Selecting Temperature Compensation Off will cause the Model 460 to ignore this data. Pressing the ▲ or ▼ keys cycles between On and Off. Push the **Enter** key to accept the new setting or the **Escape** key to leave the setting as is and return to the normal display. If the probe does not have temperature compensation, the setting is ignored.

Although the field and temperature compensation functions are not applicable to the Vector Magnitude display, the reading accuracy of the Vector Magnitude will be affected by the individual component settings.

3.8 GAUSS/TESLA

The Model 460 displays magnetic field values in gauss (G) or tesla (T). Press **Gauss/Tesla** to toggle the display between the two units. Changing gauss/tesla settings automatically applies to all X, Y, Z, and vector magnitude readings. The relation between gauss and tesla is 1 G = 0.0001 T, or 1 T = 10,000 G. When the field units are changed, relative and alarm setpoints convert to the new units with no interruption in operation. Corrected and Monitor Analog Outputs are not affected by a units change.

When tesla is selected, the Model 460 front panel displays AC or DC field values followed by T for tesla, mT for millitesla, or uT for microtesla. However, to obtain complete field readings over the IEEE-488/Serial Interface, the user must also send a **FIELDM?** command to define the multiplier.

When gauss is selected, the Model 460 front panel displays AC or DC field values followed by kG for kilogauss, G for gauss, or mG for milligauss. However, to obtain complete field readings over the IEEE-488/Serial Interface, the user must also send a **FIELDM?** command to define the multiplier.

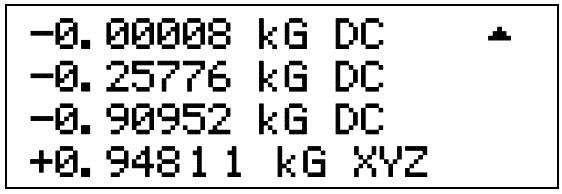
3.9 RELATIVE SET AND RELATIVE ON/OFF

The relative function lets the user see small variations in larger fields. The setpoint (or center) of the relative reading is set with the **Relative Set** key. There are two ways to enter the relative setpoint. The first method captures the field reading, nulling the present field. To use the relative function, first press the desired channel. For this example, press the channel **X** key. Then press the **Relative Set** key and observe the following display.

The first line is the just captured value (+0.0922 kG in the above example). The next line shows the value the relative setpoint was previously using (+0.8563 kG). Press **Enter** to accept the new setpoint or **Escape** to retain the old value and quit the Relative Set function.

If the captured value is not what you want, then you may enter the exact field value using the numeric keypad. Press the **Relative Set** key and change the setpoint by pressing number keys or using the ▲ or ▼ keys. Use the **Select Range** key to enter a setpoint different from the range currently being displayed. Press **Enter** to accept the new setpoint or **Escape** to return to the old value.

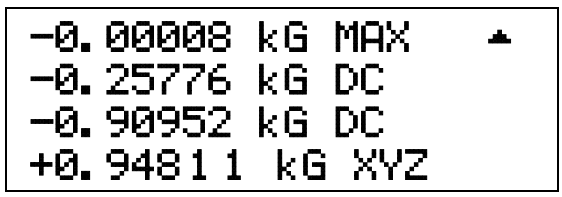
Once the relative setpoint is established, push the **Relative On/Off** key to initiate the relative function. The "Relative On" message is briefly shown in the proper line of the display. The display for that channel will then show the plus or minus deviation from the setpoint. A small delta (▲) is displayed to signify the relative display.



For example, Channel X is showing a –0.00008 kG relative reading from the +0.0922 kG captured value.

The relative feature also interacts with other features. When alarm is active, the alarm points follow the relative reading. Refer to Paragraph 3.10 for further information on setting alarms.

The Relative and Max Hold functions may be used at the same time. In this case, the relative reading becomes the maximum deviation from the relative setpoint, and the DC is replaced with the MAX indication. An example of Relative and Max Hold on at the same time is shown below.



Pressing **Max Hold** again turns off the maximum hold function, returning the relative reading to the display. Pressing the **Relative On/Off** key turns off the relative function. The "Relative Off" message is briefly displayed.

Relative Set and Relative On/Off (Continued)

NOTE: The following discussion relates only to a 3-axis configuration where X, Y, and Z are mutually orthogonal axes.

The effect that relative has on the Vector Magnitude depends on how the relative function is initiated. There are two meaningful ways to use the relative function with the Vector Magnitude. The first provides a magnitude of the difference vector, while the second provides a difference in magnitude of the field vector.

Magnitude of Difference Vector

If relative is turned on for the X, Y, and Z channels (but *not* the Vector channel), the math defining the relative reading is as follows.

$$\Delta_{XYZ} = \sqrt{\left(X_{reading} - X_{setpoint}\right)^2 + \left(Y_{reading} - Y_{setpoint}\right)^2 + \left(Z_{reading} - Z_{setpoint}\right)^2}$$

This calculates the magnitude of a difference vector.

Difference in Magnitude of the Field Vector

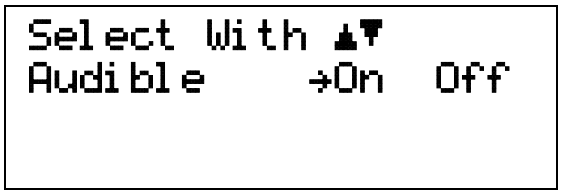
If the relative function is turned on for Vector Magnitude (but not relative for the X, Y, or Z channels), the math defining the relative reading is as follows.

$$\Delta_V = \sqrt{X_{reading}^2 + Y_{reading}^2 + Z_{reading}^2} - \sqrt{X_{setpoint}^2 + Y_{setpoint}^2 + Z_{setpoint}^2}$$

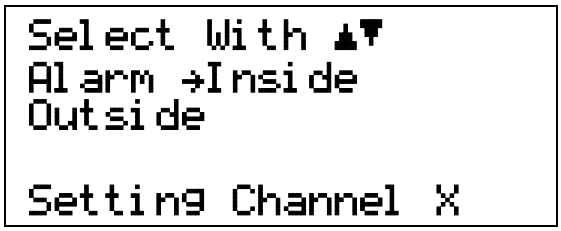
This provides the difference in magnitude of the field vector. Therefore, the two methods of relative calculation will cause different results to be displayed.

3.10 ALARM SET AND ALARM ON/OFF

The alarm gives an audible and visual indication of when the field value is either outside or inside a user specified range for that channel. Before using the alarm function, however, the user must provide two settings that define the operating parameters of the alarms. First is turning the audible alarm on or off. Second is whether the alarm will be triggered by readings inside or outside the defined magnetic field range. (Default settings are audible alarm on and alarm will be triggered outside the low and high alarm setpoints.) These settings are accomplished by choosing a channel, then pressing and holding the **Alarm On/Off** key until the following display appears.



Use the ▲ or ▼ keys to cycle between audible alarm on or off. Press **Enter** to accept the new value or **Escape** to step to the next function while retaining the old setting. (Audible is a global setting and applies to all channels.) The Model 460 will then go to the next display.

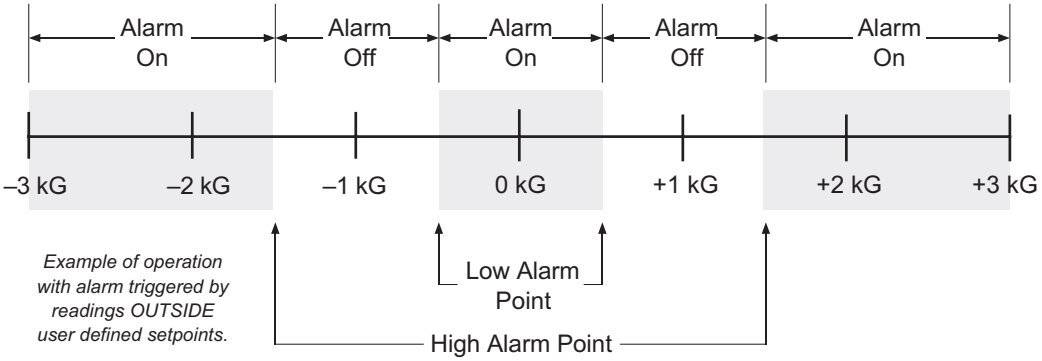


Use the ▲ or ▼ keys to cycle between the alarm triggered inside or outside alarm setpoints. (Examples of both inside and outside are given in the following paragraphs.) Press **Enter** to accept the changes or **Escape** to exit the function while retaining the old settings. All alarm functions are also available over the IEEE-488 and Serial Interfaces.

Alarm Set and Alarm On/Off (Continued)

One important point to remember is that the alarm setpoints are absolute (unsigned), i.e., only the magnitude of the field reading is used. Therefore, once alarm points are specified, any reading, whether positive or negative, will trigger the alarm.

The following example details operation with the Alarm "**Outside**" setting. For example, if the reading is to be centered on 1 kG, with the high alarm point at 1.5 kG and the low alarm point at 0.5 kG, the following diagram illustrates when the alarm would be on or off.



To enter this alarm setup, push the **Alarm Set** key. The user is first asked to enter the High Alarm Point as follows:

```
High Alarm Point
        +1.5000 kG

Setting Channel X
```

The initial range displayed is the same as the latest probe range. To set an alarm in a different range, push the **Select Range** key until the proper range is displayed. Then use the numeric keypad to enter the high alarm point. After entering the desired high alarm point, press **Enter** to accept the new value or **Escape** to retain the old value. The display proceeds to the Low Alarm Point as follows:

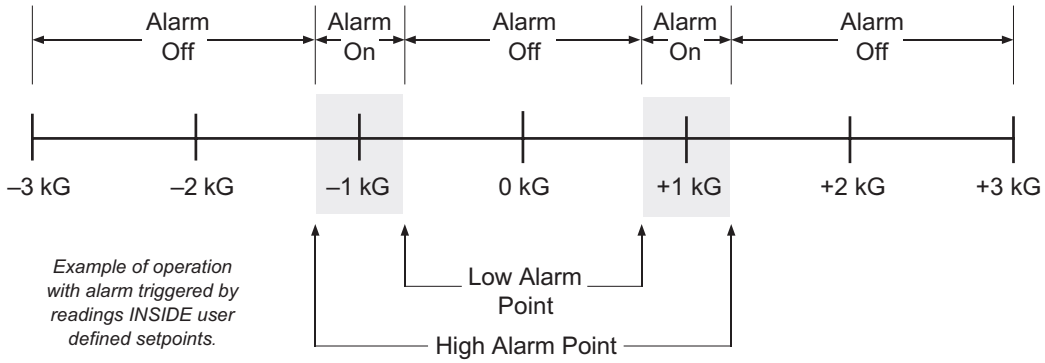
```
Low Alarm Point
        +0.5000 kG

Setting Channel X
```

The initial range displayed is the same as the latest probe range. To set an alarm in a different range, push the **Select Range** key until the proper range is displayed. Then use the numeric keypad to enter the low alarm point. After entering the desired alarm point, press **Enter** to accept the new value or **Escape** to retain the old value. Remember, the alarm setpoints are absolute (unsigned) i.e., only the magnitude of the field reading is used.

Once the proper high and low alarm points are entered, press the **Alarm On/Off** key to activate the alarm. The message "Alarm On" briefly appears on the lower line of the display the musical note will turn on steady in the upper right-hand corner of the display, signifying alarm on. To turn the alarm off, again press the **Alarm On/Off** key. The message "Alarm Off" briefly appears. When an alarm condition exists, i.e., the field reading is outside the alarm setpoints, the musical note will flash and, if turned on, the audible alarm will sound.

Alarm Set and Alarm On/Off (Continued)

The following example details how the alarm operates in the Alarm "**Inside**" setting. The alarm inside setup is useful in situations where the user is looking for an indication of a good reading, such as incoming inspections. For example, you may be sorting a number of 1 kG magnets. The magnets have an acceptable tolerance of ±0.25 kG. With the high alarm point set to 1.25 kG and the low alarm point at 0.75 kG, the following diagram illustrates when the alarm would be on or off.



Example of operation with alarm triggered by readings INSIDE user defined setpoints.

To enter this alarm setup, push the **Alarm Set** key. The user is asked to enter the High Alarm Point:

```
High Alarm Point
        +1.2500 kG

Setting Channel X
```

The initial range displayed is the same as the latest probe range. To set an alarm in a different range, push the **Select Range** key until the proper range is displayed. Then use the numeric keypad to enter the high alarm point. After entering the desired high alarm point, press **Enter** to accept the new value or **Escape** to retain the old value. The display proceeds to the Low Alarm Point as follows:

```
Low Alarm Point
        +0.7500 kG

Setting Channel X
```

The initial range displayed is the same as the latest probe range. To set an alarm in a different range, push the **Select Range** key until the proper range is displayed. Then use the numeric keypad to enter the low alarm point. After entering the desired alarm point, press **Enter** to accept the new value or **Escape** to retain the old value. The alarm setpoints are absolute (unsigned) i.e., only the magnitude of the field reading is used.

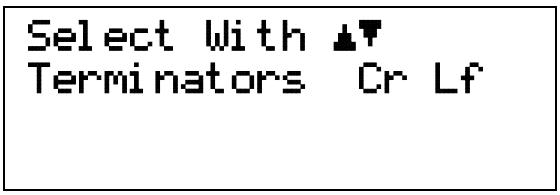
Once the proper high and low alarm points are entered, press the **Alarm On/Off** key to activate the alarm. The message "Alarm On" briefly appears on the lower line of the display the musical note will turn on steady in the upper right-hand corner of the display, signifying alarm on. To turn the alarm off, again press the **Alarm On/Off** key. The message "Alarm Off" briefly appears. When a magnetic item is within tolerance, i.e., the field reading is inside the alarm setpoints, the musical note will flash and, if turned on, the audible alarm will sound.

3.11 LOCAL AND INTERFACE

Normal operations from the front panel and keypad are referred to as 'Local' operation. However, the IEEE-488 and Serial Interfaces are included to provide remote operation. If the Model 460 is connected to a suitably equipped computer, the user has the option to permit or inhibit front panel operation. The **Local** key acts as a toggle between local (front panel functional) or remote (front panel disabled). The letter "R" is displayed in the upper right side of the display to signify the Remote mode is activated.

The **Interface** key has three functions. The first and second is to set the IEEE-488 Address and Terminators (refer to Paragraph 4.1). The third is to set the Baud rate for the Serial Interface (refer to Paragraph 4.2). Press **Interface** to display the three windows in the order shown below.

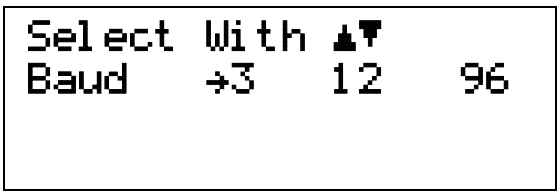
Press the ▲ or ▼ keys to increment or decrement the IEEE Address to the required number. Press **Enter** to accept the new number or **Escape** to leave the existing number. The Model 460 automatically proceeds to the IEEE-488 Terminator display as follows.



Press the ▲ or ▼ keys to cycle through the following IEEE-488 Terminator choices. (Terminators are fixed to Cr Lf for the Serial Interface.)

Cr Lf	Carriage Return and Line Feed.
Lf Cr	Line Feed and Carriage Return.
LF	Line Feed.
EOI	End Or Identify.

The Model 460 automatically proceeds to the Baud display as follows.



Press the ▲ or ▼ keys to cycle through the choices of 300, 1200, or 9600 Baud. Press **Enter** to accept the new number or **Escape** to keep the existing setting and return to the normal display.

3.12 DISPLAY

The **Display** key permits the user to set the illumination level of the front panel vacuum fluorescent display. Pressing the **Display** key brings up the following display.

Press the ▲ or ▼ keys to cycle through the choices of 0 to 7, where 0 is the dimmest and the 7 is the brightest display. The default setting is 4. Press the **Enter** key to accept the new number or the **Escape** key to keep the existing setting and return to the normal display. It is recommended that the brightness be kept as low as comfortably readable.

3.13 ANALOG OUT

There are two types of analog outputs available on the rear panel of the Model 460. They are the Corrected and Monitor Analog Outputs. A single corrected analog output is provided (whose source is user definable), and three monitor outputs are provided (one for each channel). The corrected and monitor outputs use BNC connectors with the center conductor carrying the signal and the outer portion the ground. To use the corrected analog output in control mode. refer to Paragraph 3.16.2.

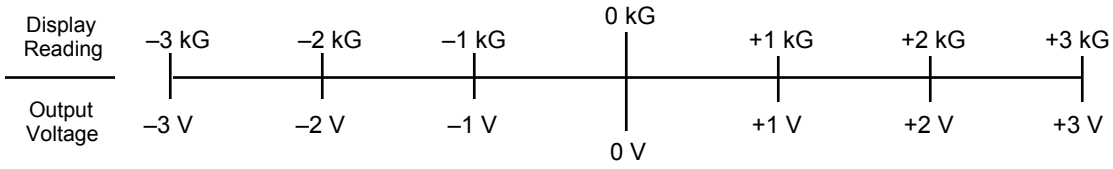
3.13.1 Corrected Analog Out

The Corrected Analog Output is a DC value proportional to the displayed field. The displayed field reading may be corrected for probe non-linearity, zero offset, and temperature. This output is not a real time signal, but is updated at the same rate as the display (4 times per second).

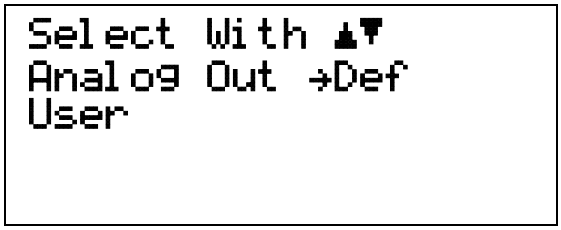
The output range of the corrected analog output is ±3 volts. A jumper is located inside the Model 460 that can change the corrected analog output to ±10 volts. This jumper will be set at the factory per the customer's original request. The jumper can be changed in the field, but may shift the calibration slightly. Help in locating the jumper (JMP2) is provided in Figure 6-9. The following examples assume a ±3 volt setting.

NOTE: Only one channel source may be chosen at a time by the user.

The default range of the Corrected output is ±3 volts equals ± full scale for the selected range. For the example below, the 3 kG range was selected.

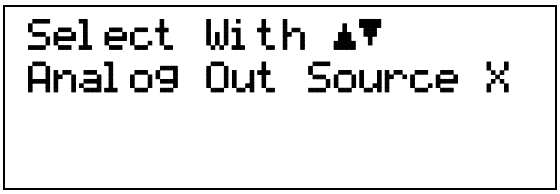


To select the default range, press the Analog Out key and observe the following display.



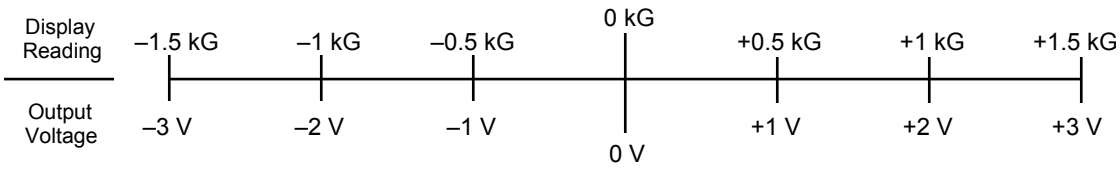
Corrected Analog Out (Continued)

Press the **Analog Out**, ▲, or ▼ key to cycle the arrow (→) to Def (Default). Press the **Enter** key. You will then see the channel selection display as follows.

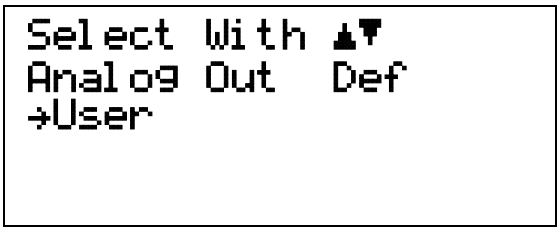


Press the ▲ or ▼ key to cycle the analog output source from channel X, Y, Z, or Vector. In this case, we chose Channel X. Press the **Enter** key. The Corrected Analog Output is now set for ±3V = ±3 kG.

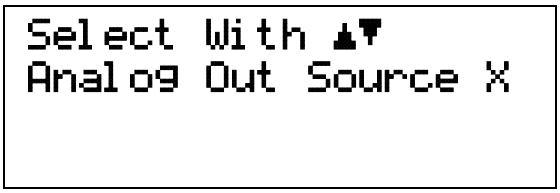
The user also has the option to change the scaling of the Corrected Analog Output. User defined scaling can improve resolution over a selected area of interest. This can best be explained by a couple of examples. The first example is a symmetrical scaling similar to the default scale.



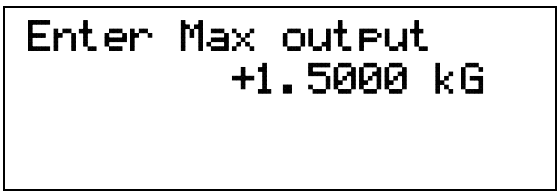
To enter this scale, press the **Analog Out** Key. Press the **Analog Out**, ▲, or ▼ key to cycle the arrow (→) to User as shown below.



Press the **Analog Out**, ▲, or ▼ key to cycle the arrow (→) to User. Press the **Enter** key. You will then see the channel selection display as follows.



Press the ▲ or ▼ key to cycle the analog output source from channel X, Y, Z, or Vector. In this case, we chose Channel Y. Press the **Enter** key and observe the following display.



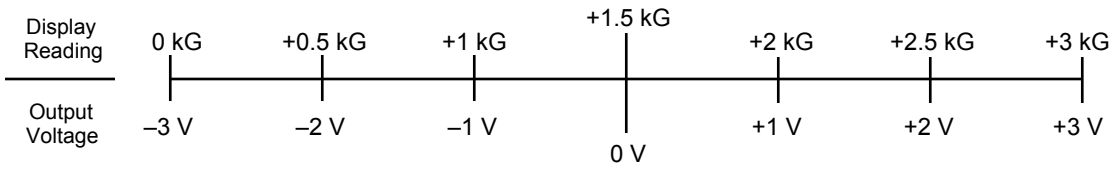
Corrected Analog Out (Continued)

Enter the numbers 1.5 on the numerical keypad and press the **Enter** key. A maximum output of +1.5 kG has now been placed into memory. Upon pressing **Enter**, the following display will appear.

```
Enter Min output
        -1.5000 kG
```

Enter the numbers –1.5 on the numerical keypad and press the **Enter** key. A minimum output of –1.5 kG has now been placed into memory. Changes to the Corrected Analog Output are immediately observable.

The second example is an asymmetrical scaling which demonstrates the versatility of user selectable scaling.



To enter this scale, press the **Analog Out** Key. Press the **Analog Out**, ▲, or ▼ key to cycle the arrow (→) to User as shown below.

```
Select With ▲▼
Analog Out →Def
→User
```

Press the **Analog Out**, ▲, or ▼ key to cycle the arrow (→) to Def (Default). Press the **Enter** key. The display will automatically step to the Analog Output Source selection display shown below:

```
Select With ▲▼
Analog Out Source X
```

Press the ▲ or ▼ key to cycle the analog output source from channel X, Y, Z, or Vector. In this case, we chose Channel X. Press the **Enter** key and observe the following display.

```
Enter Max output
        +3.0000 kG
```

Corrected Analog Out (Continued)

Enter the number 3 on the numerical keypad and press the **Enter** key. A maximum output of +3.0 kG has now been placed into memory. Upon pressing **Enter**, the following display will appear.

Enter the numbers 0.0 on the numerical keypad and press the **Enter** key. A minimum output of 0.0 kG has now been placed into memory. Changes to the Corrected Analog Output are immediately observable.

For best results, there should be at least 100 counts between minimum and maximum for the range. For example, if the 3.0000 kG range was selected, and if the minimum scale setting was 1.0000 kG, the maximum setting should be 1.0100 kG or greater.

3.13.2 Monitor Analog Out

There are three Monitor Analog Outputs on the rear panel of the Model 460. The three outputs correspond to channels X, Y, and Z. There is no monitor output for Vector Magnitude. The Monitor Analog Outputs are real-time analog signals proportional to the magnetic field. The scale of each Monitor Analog Output is ±3 volts for full scale of selected range. The Monitor Analog Outputs are not as accurate as the Corrected Monitor Output, but have the full DC to 400 Hz. bandwidth of the AC measurement. Most of the error is on lower ranges and results from zero offsets in the probe and instrument. The error can be minimized if the output voltage observed at zero field can be subtracted from the live output. See Figure 3-4 for the Monitor Analog Output frequency response.

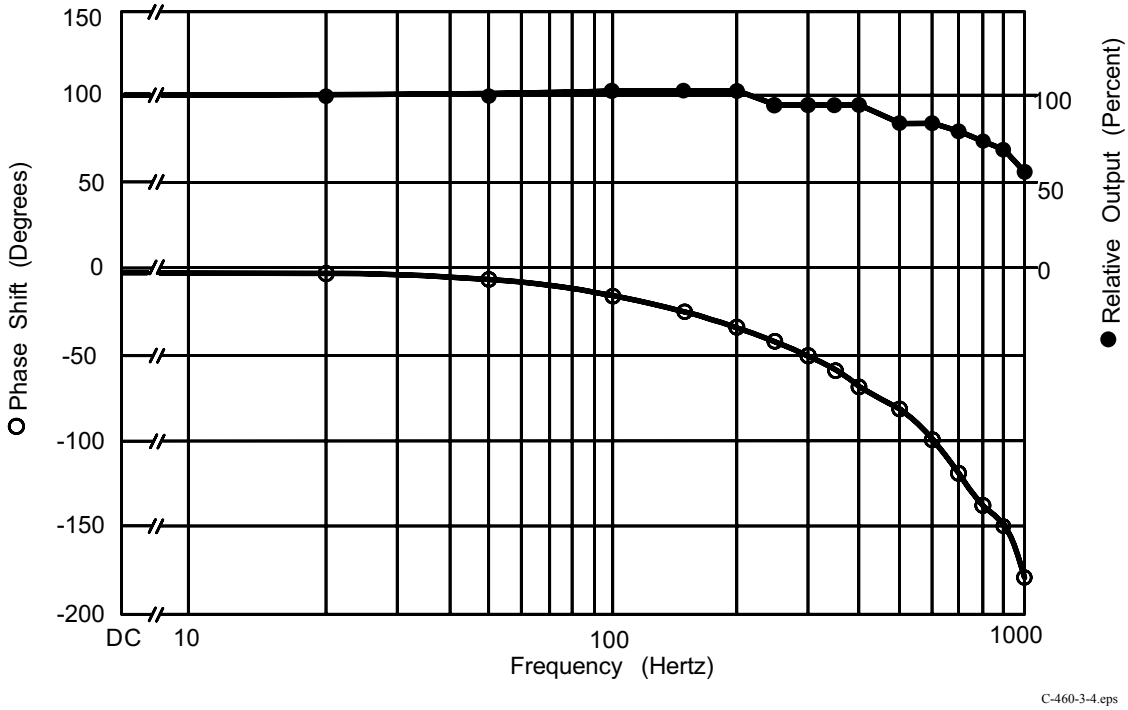
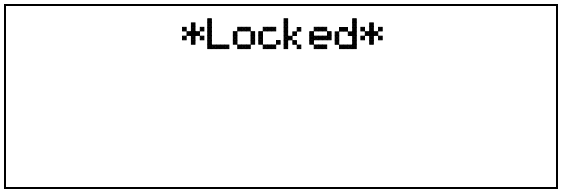


Figure 3-4. Monitor Analog Output Frequency Response

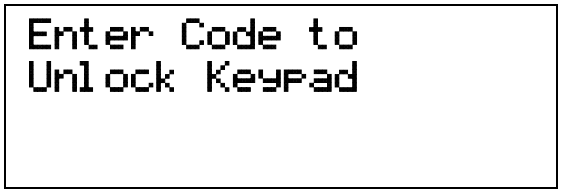
3.14 LOCKING AND UNLOCKING THE KEYBOARD

The Model 460 front panel keyboard may be locked, preventing unauthorized changes to the settings. To lock the keyboard, press and hold the **Enter** key (≈10 seconds) until the following display is seen.

Now enter the 3-digit lock code (the factory default code is 123.) Upon entry of the third number, the display reverts to the normal display. The keyboard is now locked. After locking the keypad, any attempt to change settings causes the following message to briefly be displayed.



To unlock the keyboard, again press and hold the **Enter** key until the following display is seen.



Enter the lock code again. Upon entry of the third number, the display reverts to the normal display and the keyboard is unlocked.

The lock code may be changed using either the IEEE-488 or Serial Computer Interface. If the instrument is reset, the lock code will revert to 123. The instrument cannot be reset when the keyboard is locked.

3.15 FACTORY DEFAULT SETTINGS

If the keypad is unlocked and the Model 460 is in local mode, the user may press and hold **Escape** key for ≈20 seconds to return the instrument to factory default settings shown below. Other gaussmeter calibration information and probe data are not affected by this reset. The probe should be zeroed after completing this operation.

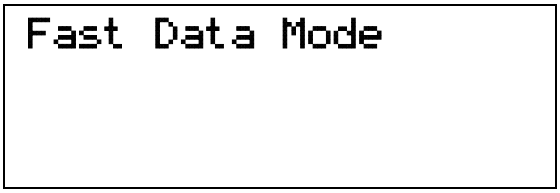
AC/DC	DC	Filter Window	1%
Address	12	Gauss/Tesla	Gauss
Alarm	Off	Keypad	Not Locked
Alarm Trigger	Outside	Keypad Setting Channel	X
Analog Out	Default	Local/Remote	Local
Analog Out Source	X	Lock Code	123
Audible Alarm	On	Max Hold	Off
Auto Range	Off	Peak/RMS	RMS
Baud	300	Range	Highest Range For Probe
Brightness	4	Relative	Off
Display	X,Y,Z On, Vector On	Sleep	Off
Fast Data Mode	Off	Temp. Compensation	On
Field Compensation	On	Terminators	CR/LF
Filter	Off	Vector Source	XYZ
Filter Number	8		

3.16 SPECIAL FUNCTIONS

The Model 460 Gaussmeter has some interesting special functions used with the various computer interfaces. Fast Data Acquisition Mode is discussed in Paragraph 3.16.1. Analog Output Control Mode in Paragraph 3.16.2. And finally, Sleep mode in Paragraph 3.16.3.

3.16.1 Fast Data Acquisition Mode

In normal operation, the instrument updates the display, computer interfaces, and the corrected analog output at a rate of 4 readings per second. A Fast Data Mode has been included to increase the data rate when operating with either the IEEE-488 or Serial Interface. While the corrected analog output update rate does correspond to the Fast Data Mode, the front panel display will not operate in this mode. Use the **FAST** command over one of the computer interfaces to activate this mode. When in Fast Data Mode, the user will see the following front panel display:



Without display overhead, the instrument can take 18 XYZ readings each second with Vector Magnitude turned off, or 14 XYZ and Vector Magnitude readings each second with Vector Magnitude turned on. An efficiently written IEEE-488 program can return all 18 XYZ (or 14 XYZV) readings using the **ALLF?** command to query the field measurement data without slowing the instrument down. Use the **ONOFF** command to turn the vector magnitude on or off. When the Vector Magnitude is turned off, the instrument will still respond to the **ALLF?** command with four readings (X, Y, Z, and V), but the fourth reading will consist of meaningless data that should be ignored. The Serial Interface is capable of 14 readings per second in the Fast Data Mode. When using either interface, never try to read faster than the update rate. Specific information on command syntax is provided in Paragraph 5.3.

Fast Data Acquisition Mode (Continued)

NOTE: When Fast Data Mode is activated, the following Model 460 functions are disabled: Relative, Max Hold, Alarms, and Autorange.

NOTE: Temperature compensation (if applicable) is based on the last temperature reading prior to activation of the FAST DATA MODE. The temperature is not updated during the use of FAST DATA.

The additional overhead associated with Serial Communication will slow the instrument communicating over the Serial Interface to a maximum of 14 readings per second at 9600 Baud. When using the Serial Interface, never try to read faster than the update rate.

3.16.2 Analog Output Control Mode

It is sometimes convenient to use the corrected analog output as a control voltage output instead of an analog output proportional to measured field. A set of computer interface commands control the digital-to-analog converter (DAC) for the corrected analog output. One common application is using the output to program an electromagnet power supply. By using the analog output, the user can avoid purchasing a magnet supply controller and adding a separate interface to their computer.

The Model 460 software dated 10/1/94 and newer supports this feature. Update software for older Model 460s is available at no charge. The actual output voltage and voltage resolution depends on an instrument hardware setting.

In a standard Model 460, the output range of the corrected analog output is ±3 volts. A jumper is located inside the gaussmeter that can change the corrected analog output to ±10 volts. This jumper is set at the factory per the customer's original request. The jumper can be changed in the field, but may shift the calibration slightly. See Figure 6-9 to locate jumper JMP2.

Output Range:	±3 volts	±10 volts
Resolution:	0.37 mV	1.2 mV

Two commands control the corrected analog output via the IEEE-488 or Serial Interface. The **ANOD** command specifies interface control of the output; set it to "2". Send this command only once. The **ANOD?** query confirms the change. This setting will not change if the instrument is powered off, but it can be changed back to normal operation from the front panel.

The **AOCON** command sets bipolar output voltage in percent of full scale. The setting format of ±xxx.xx; allows for a sign and a resolution of 0.01%. As a safety precaution, this setting always equals zero if the instrument looses power or is turned off. The setting cannot be changed from the front panel. The **AOCON?** query confirms the change. Example: Sending **AOCON –50.25** sets output to –50.25% of full scale. This is -5.025 V for a ±10 V output or -1.5075 V for a ±3 V output.

3.16.3 Sleep Mode

Sleep mode is provided to allow the user to turn off all three current sources at one time. To accomplish this, the **SLEEP** command is issued over one of the computer interfaces. **SLEEP 0** turns the Sleep Mode on, while **SLEEP 1** turns Sleep Mode off. This command is useful when gathering a sensitive measurement elsewhere in a system where the current sources in the gaussmeter may interfere with the measurement.

NOTE: What the **ONOFF** command can accomplish for individual channels, **SLEEP** can do for all three channels simultaneously.

3.17 PROBE CONSIDERATIONS

To avoid damage and for best results during use, the probes have a number of handling and accuracy requirements that must be observed. Changing probes is discussed in Paragraph 3.17.1. Probe handling is discussed in Paragraph 3.17.2. Probe operation is discussed in Paragraph 3.17.3. Finally, accuracy considerations are provided in Paragraph 3.17.4.

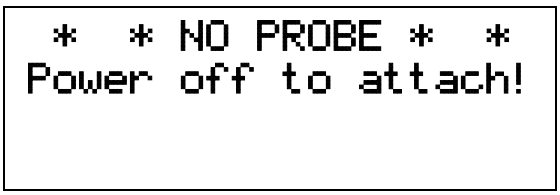
3.17.1 Changing Probes

A 512-byte Electrically Erasable Programmable Read Only Memory (EEPROM) is included in each probe. The EEPROM stores specific information that the gaussmeter requires for operation. The information includes serial number, probe sensitivity, and temperature and field compensation data.

CAUTION: The probe must be connected to the rear of the instrument before applying power to the gaussmeter. Probe memory may be erased if connected with power on.

When the instrument is powered up, the probe memory is downloaded to the gaussmeter. This is how the gaussmeter knows which ranges are available and which error correction to apply. To change probes, first turn power off, remove the existing probe, and then plug in the new probe. When power is restored, the characteristics of the new probe are downloaded to the gaussmeter memory. Normal operation may continue after the new probe offset is nulled using the Zero Probe operation.

If the instrument is powered up with no probe attached, the following message is displayed.



If any one channel has no probe attached, excitation current to the channel is turned off, the corresponding line of the display is blank, and the message NO PROBE briefly appears when pressing and holding the X, Y, or Z channel key.

If the display remains blank after the probe is attached and power restored to the unit, then the channel is probably turned OFF. Refer to Paragraph 3.1.3 to turn the channel ON. For best results, warm up the instrument and probe for at least 5 minutes before zeroing the probe, and at least 30 minutes for rated accuracy. The probe and the zero gauss chamber should be at the same temperature.

3.17.2 Probe Handling

Although every attempt has been made to make the probes as sturdy as possible, the probes are still fragile. This is especially true for the exposed sensor tip of some probes. Care should be taken during measurements that no pressure is placed on the tip of the probe. The probe should only be held in place by securing at the handle. The probe stem should never have force applied. Any strain on the sensor may alter the probe calibration, and excessive force may destroy the Hall generator.

CAUTION: Care must be exercised when handling the probe. The tip of the probe is very fragile. Stressing the Hall sensor can alter its calibration. Any excess force can easily break the sensor. Broken sensors are not repairable.

Avoid repeated flexing of the stem of a flexible probe. As a rule, the stem should not be bent more than 45° from the base. See Figure 3-5. Force should never be applied to the tip of the probe. On all probes, do not pinch or allow cables to be struck by any heavy or sharp objects. Although damaged or severed cables should be returned to Lake Shore for repair, please understand that probes are not always repairable.

When probes are installed on the gaussmeter but not in use, the protective tubes provided with many probes should be placed over the probe handle and stem in order to protect the tip. When the gaussmeter is not in use, the probes should be stored separately in some type of rigid container. The cardboard and foam container that Lake Shore probes are shipped in may be retained for probe storage. For further details on available accessories and probes, refer to Chapter 5.

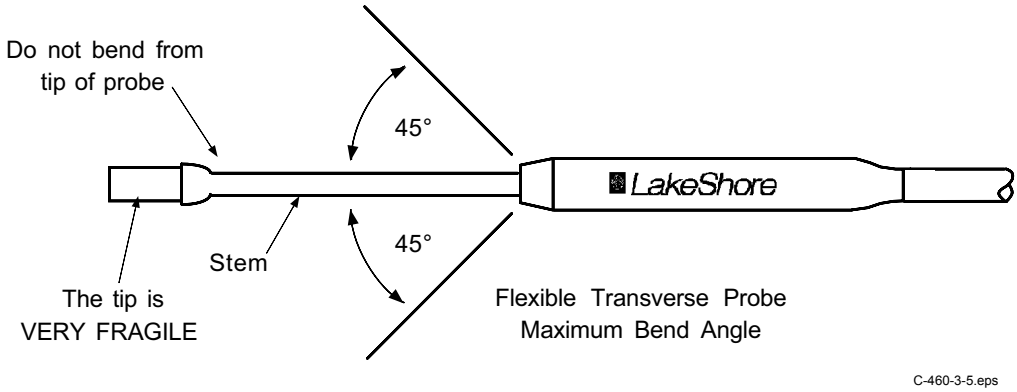


Figure 3-5. Maximum Flexible Probe Bend Radius

3.17.3 Probe Polarity

In the DC mode of operation, the orientation of the probe affects the polarity reading of the gaussmeter. On a transverse probe, the Lake Shore name printed on the handle indicates the side for positive (+) flux entry. On an axial probe, positive (+) flux entry is always from the front of the probe. On 2-axis probes, the positive flux entry for B_X is on the flat side of the probe tip, and B_Y is from the front of the probe. On 3-axis probes, the positive flux entry for B_X and B_Y are on the flat sides of the probe tip, and B_Z is from the front of the probe. Small labels on the probe tip indicate that entry of magnetic flux causes a positive reading. See Figure 3-6.

If the exact direction of the magnetic field is unknown, the proper magnitude is determined by turning on **Max Hold** and slowly adjusting the probe. As the probe turns and the measured field rises and falls, its maximum value is held on the display. Make note of the probe orientation at the maximum reading to identify the field orientation.

NOTE: Determining field direction is not necessary when using a 3-axis probe (with Vector ON).

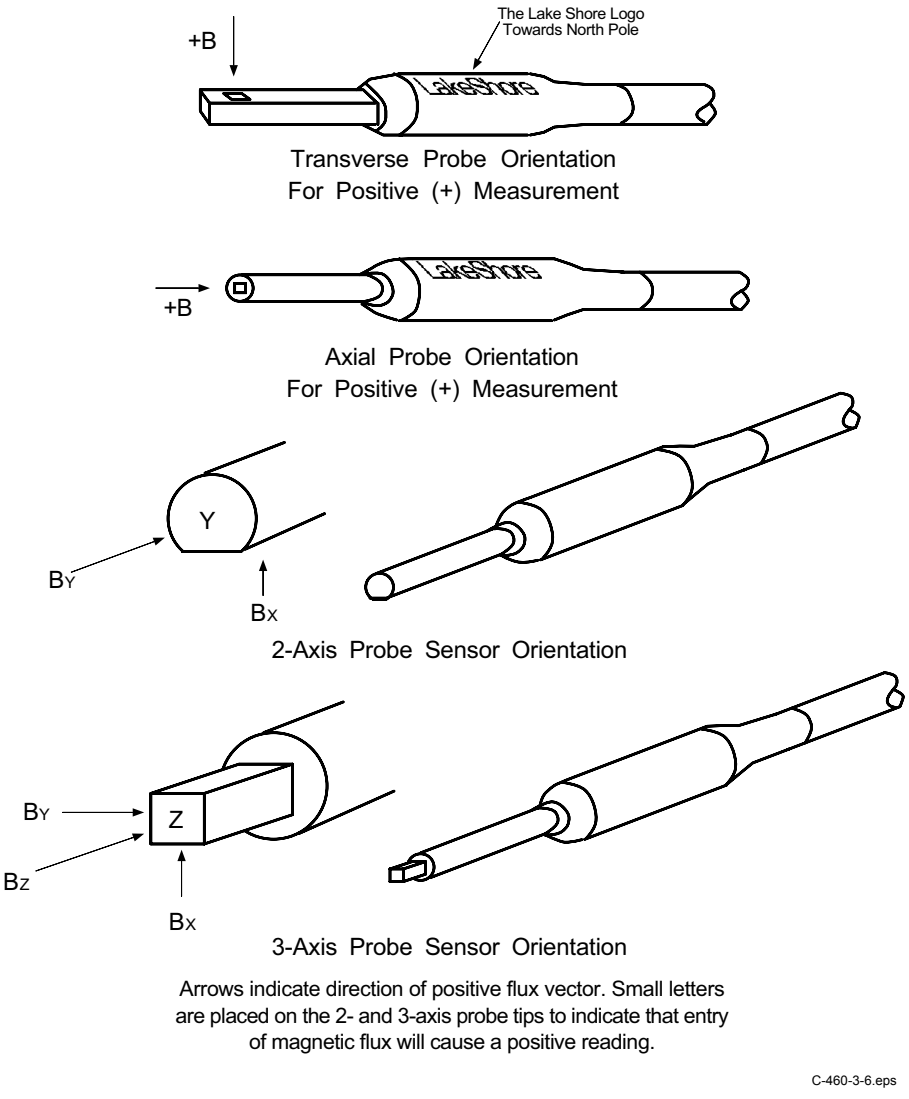


Figure 3-6. Probe Orientation For Positive Measurement

3.17.4 Probe Accuracy Considerations

NOTE: Probe readings are dependent upon the angle of the sensor in relation to the magnetic field. The further from 90° the angle between the probe and the field, the greater the percentage of error. For example, a 5° deviation causes a 0.4% error, a 10° deviation causes a 1.5% error, etc.

NOTE: For best results, the instrument and probe should warm up for at least 5 minutes before zeroing the probe, and at least 30 minutes for rated accuracy. The probe and the zero gauss chamber should be at the same temperature.

The user must consider all the possible contributors to the accuracy of the reading. Both the probe and gaussmeter have accuracy specifications that may impact the actual reading. The probe should be zeroed before making critical measurements. The zero probe function is used to null (cancel) out the zero offset of the probe or small magnetic fields. It is normally used in conjunction with the zero gauss chamber, but may also be used with an open probe (registering the local earth magnetic field). Users wishing to cancel out large magnetic fields should use the Relative function. Refer to Paragraph 3.9.

Probe temperature can also affect readings. Refer to the two separate temperature coefficients listed on the specification sheet. The High Stability (HST) probes exhibit a low temperature coefficient of gain due to the inherent thermal stability of the materials used in its construction.

NOTE: The following discussion relates to the use of single-axis probes. Three-axis probes are already set at right angles and therefore do not exhibit these angle induced errors.

When using single-axis probes, readings are dependent on the angle of the sensor (Hall sensor) in relation to the magnetic field. Maximum output occurs when the flux vector is perpendicular to the plane of the sensor. This is the condition that exists during factory calibration. The greater the deviation from orthogonality (from right angles in either of three axes), the larger the error of the reading. For example, a 5° variance on any one axis causes a 0.4% error, a 10° misalignment induces a 1.5% error, etc. See Figure 3-7.

Tolerance of instrument, probe, and magnet must be considered for making critical measurements. The accuracy of the gaussmeter reading is better than ±0.20% of reading and ±0.05% of range. Absolute accuracy readings for gaussmeters and Hall probes is a difficult specification to give, because all the variables of the measurement are difficult to reproduce. For example, a 1° error in alignment to the magnetic field causes a 0.015% reading error. Finally, the best probes have an accuracy of ±0.15%. This implies that the absolute accuracy measurement of a magnetic field is not going to reliably be better than ±0.15% under the best of circumstances, and more likely to be 0.20% to 0.25%.

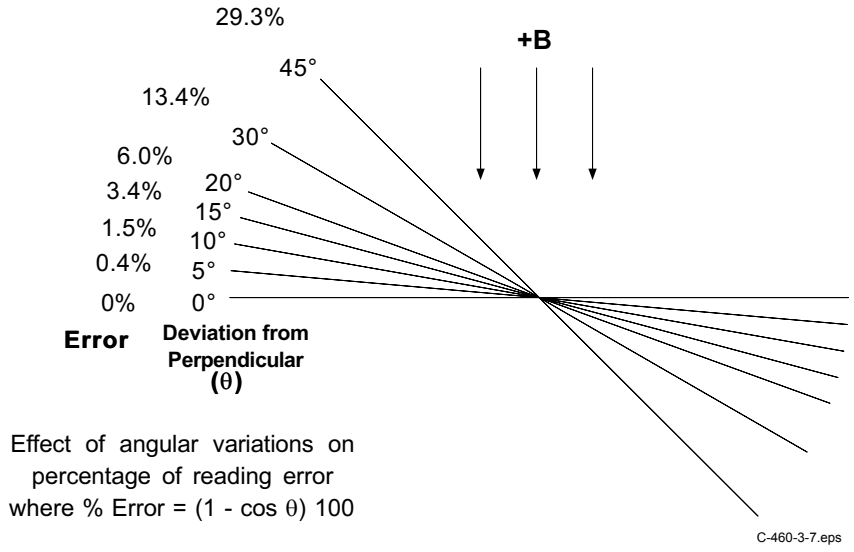


Figure 3-7. Effect Of Angle On Measurements

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CHAPTER 4

COMPUTER INTERFACE OPERATION

4.0 GENERAL

This chapter provides operational instructions for the computer interface for the Lake Shore Model 460 Gaussmeter. Either of the two computer interfaces provided with the Model 460 permit remote operation. The first is the IEEE-488 Interface described in Paragraph 4.1. The second is the Serial Interface described in Paragraph 4.2. The two interfaces share a common set of commands detailed in Paragraph 4.3. Only one of the interfaces can be used at a time.

4.1 IEEE-488 INTERFACE

The IEEE-488 Interface is an instrumentation bus with hardware and programming standards that simplify instrument interfacing. The Model 460 IEEE-488 Interface complies with the IEEE-488.2-1987 standard and incorporates its functional, electrical, and mechanical specifications unless otherwise specified in this manual.

All instruments on the interface bus perform one or more of the interface functions of TALKER, LISTENER, or BUS CONTROLLER. A TALKER transmits data onto the bus to other devices. A LISTENER receives data from other devices through the bus. The BUS CONTROLLER designates to the devices on the bus which function to perform. The Model 460 performs the functions of TALKER and LISTENER but cannot be a BUS CONTROLLER. The BUS CONTROLLER is the digital computer which tells the Model 460 which functions to perform.

Below are Model 460 IEEE-488 interface capabilities:

- **SH1:** Source handshake capability.
- **RL1:** Complete remote/local capability.
- **DC1:** Full device clear capability.
- **DT0:** No device trigger capability.
- **C0:** No system controller capability.
- **T5:** Basic TALKER, serial poll capability, talk only, unaddressed to talk if addressed to listen.
- **L4:** Basic LISTENER, unaddressed to listen if addressed to talk.
- **SR1:** Service request capability.
- **AH1:** Acceptor handshake capability.
- **PP0:** No parallel poll capability.
- **E1:** Open collector electronics.

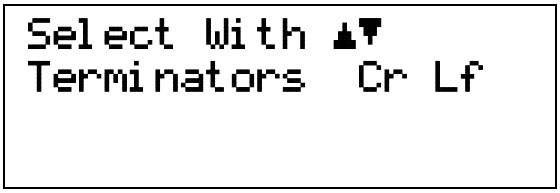
NOTE: The Model 460 IEEE-488 Interface requires that repeat addressing be enabled on the bus controller.

Instruments are connected to the IEEE-488 bus by a 24-conductor connector cable as specified by the standard. Refer to Paragraph 6.5.1. Cables can be purchased from Lake Shore or other electronic suppliers. Cable lengths are limited to 2 meters for each device and 20 meters for the entire bus. The Model 460 can drive a bus with up to 10 loads. If more instruments or cable length is required, a bus expander must be used.

4.1.1 IEEE-488 Interface Settings

If using the IEEE-488 interface, you must set the IEEE Address and Terminators. Press the **Interface** key. The first screen selects Serial Interface Baud Rate, and therefore is skipped by pressing the **Enter** key. The Address screen is then displayed.

Press the ▲ or ▼ keys to increment or decrement the IEEE Address to the desired number. Press **Enter** to accept new number or **Escape** to retain the existing number. Pressing **Enter** displays the Terminators screen.



Press the ▲ or ▼ keys to cycle through the following Terminator choices: CR/LF, LF/CR, LF, and EOI. To accept changes or the currently displayed setting, push **Enter**. To cancel changes, push **Escape**. Power down the Model 460 then back up again to allow other devices on the IEEE-488 bus to recognize a new Address or Terminator setting.

4.1.2 IEEE-488 Command Structure

The Model 460 supports several command types. These commands are divided into three groups.

1. **Bus Control** – refer to Paragraph 4.1.2.1.
   - **a.** Universal
     - (1) Uniline
     - (2) Multiline
   - **b.** Addressed Bus Control
2. **Common** – refer to Paragraph 4.1.2.2.
3. **Interface** and **Device Specific** – refer to Paragraph 4.1.2.3.
4. **Message Strings** – Refer to Paragraph 4.1.2.4.

4.1.2.1 Bus Control Commands

A Universal Command addresses all devices on the bus. Universal Commands include Uniline and Multiline Commands. A Uniline Command (Message) asserts only a single signal line. The Model 460 recognizes two of these messages from the BUS CONTROLLER: **Remote (REN)** and **Interface Clear (IFC)**. The Model 460 sends one Uniline Command: **Service Request (SRQ)**.

REN (Remote) – Puts the Model 460 into remote mode.

IFC (Interface Clear) – Stops current operation on the bus.

SRQ (Service Request) – Tells the bus controller that the Model 460 needs interface service.

A Multiline Command asserts a group of signal lines. All devices equipped to implement such commands do so simultaneously upon command transmission. These commands transmit with the Attention (ATN) line asserted low. The Model 460 recognizes two Multiline commands:

LLO (Local Lockout) – Prevents the use of instrument front panel controls.

DCL (Device Clear) – Clears Model 460 interface activity and puts it into a bus idle state.

Bus Control Commands (Continued)

Finally, Addressed Bus Control Commands are Multiline commands that must include the Model 460 listen address before the instrument responds. Only the addressed device responds to these commands. The Model 460 recognizes three of the Addressed Bus Control Commands:

SDC (Selective Device Clear) – The SDC command performs essentially the same function as the DCL command except that only the addressed device responds.

GTL (Go To Local) – The GTL command is used to remove instruments from the remote mode. With some instruments, GTL also unlocks front panel controls if they were previously locked out with the LLO command.

SPE (Serial Poll Enable) and **SPD (Serial Poll Disable)** – Serial polling accesses the Service Request Status Byte Register. This status register contains important operational information from the unit requesting service. The SPD command ends the polling sequence.

4.1.2.2 Common Commands

Common Commands are addressed commands which create commonalty between instruments on the bus. All instruments that comply with the IEEE-488 1987 standard share these commands and their format. Common commands all begin with an asterisk. They generally relate to "bus" and "instrument" status and identification. Common query commands end with a question mark (?). Model 460 common commands are detailed in Paragraph 4.3.1 and summarized in Table 4-8.

4.1.2.3 Interface and Device Specific Commands

Device specific commands are addressed commands. The Model 460 supports a variety of device specific commands to program instruments remotely from a digital computer and to transfer measurements to the computer. Most device specific commands perform functions also performed from the front panel. Model 460 device specific commands are detailed in Paragraphs 4.3.2 thru 4.3.4 and summarized in Table 4-8.

4.1.2.4 Message Strings

A message string is a group of characters assembled to perform an interface function. There are three types of message strings commands, queries and responses. The computer issues command and query strings through user programs, the instrument issues responses. Two or more command strings can be chained together in one communication but they must be separated by a semi-colon (;). Only one query is permitted per communication but it can be chained to the end of a command. The total communication string must not exceed 64 characters in length.

A command string is issued by the computer and instructs the instrument to perform a function or change a parameter setting. When a command is issued, the computer is acting as 'talker' and the instrument as 'listener'. The format is:

```
<command mnemonic><space><parameter data><terminators>.
```

Command mnemonics and parameter data necessary for each one is described in Paragraph 4.3. Terminators must be sent with every message string.

A query string is issued by the computer and instructs the instrument which response to send. Queries are issued similar to commands with the computer acting as 'talker' and the instrument as 'listener'. The query format is:

```
<query mnemonic><?><space><parameter data><terminators>.
```

Query mnemonics are often the same as commands with the addition of a question mark. Parameter data is often unnecessary when sending queries. Query mnemonics and parameter data if necessary is described in Paragraph 4.3. Terminators must be sent with every message string. Issuing a query does not initiate a response from the instrument.

A response string is sent by the instrument only when it is addressed as a 'talker' and the computer becomes the 'listener'. The instrument will respond only to the last query it receives. The response can be a reading value, status report or the present value of a parameter. Response data formats are listed along with the associated queries in Paragraph 4.3.

4.1.3 Status Registers

There are two status registers: the Status Byte Register described in Paragraph 4.1.3.1, and the Standard Event Status Register in Paragraph 4.1.3.2.

4.1.3.1 Status Byte Register and Service Request Enable Register

The Status Byte Register consists of a single byte of data containing six bits of information about the condition of the Model 460.

STATUS BYTE REGISTER FORMAT

Bit –	7	6	5	4	3	2	1	0
Weighting –	128	64	32	16	8	4	2	1
Bit Name –	Not Used	SRQ	ESB	OVI	Not Used	ALM	RNG	FDR

If the Service Request is enabled, any of these bits being set will cause the Model 460 to pull the SRQ management low to signal the BUS CONTROLLER. These bits are reset to zero upon a serial poll of the Status Byte Register. These reports can be inhibited by turning their corresponding bits in the Service Request Enable Register to off.

The Service Request Enable Register allows the user to inhibit or enable any of the status reports in the Status Byte Register. The ✱SRE command is used to set the bits. If a bit in the Service Request Enable Register is set (1), then that function is enabled. Refer to the ✱SRE command discussion.

Service Request (SRQ) Bit (6) – Determines whether the Model 460 is to report via the SRQ line and four bits determine which status reports to make. If bits 0, 1, 2, 4 and/or 5 are set, then the corresponding bit in the Status Byte Register will be set. The Model 460 will produce a service request only if bit 6 of the Service Request Enable Register is set. If disabled, the Status Byte Register can still be read by the BUS CONTROLLER by means of a serial poll (SPE) to examine the status reports, but the BUS CONTROLLER will not be interrupted by the Service Request. The ✱STB common command will read the Status Byte Register but will not clear the bits.

The bit assignments are discussed below as they pertain to the Status Byte Register. These reports can only be made if they have been enabled in the Service Request Enable Register.

Standard Event Status (ESB) Bit (5) – When bit 5 is set, it indicates if one of the bits from the Standard Event Status Register has been set. (Refer to Paragraph 4.1.3.2.)

Overload Indicator (OVI) Bit (4) – If the display has an overload condition on any channel, this bit is set and a Service Request is issued if enabled.

Alarm (ALM) Bit (2) – This bit is set when an alarm condition exists on any channel. This condition will latch until acknowledged by the bus controller.

Range Change (RNG) Bit (1) – Range changed in Auto Range mode on any channel.

Field Data Ready (FDR) Bit (0) – When this bit is set, new valid field readings are available.

4.1.3.2 Standard Event Status Register and Standard Event Status Enable Register

The Standard Event Status Register supplies various conditions of the Model 460.

STANDARD EVENT STATUS REGISTER FORMAT

Bit –	7	6	5	4	3	2	1	0
Weighting –	128	64	32	16	8	4	2	1
Bit Name –	PON	Not Used	CME	EXE	DDE	QYE	Not Used	OPC

Bits 2 and 6 are not used. The user will only be interrupted with the reports of this register if the bits have been enabled in the Standard Event Status Enable Register and if bit 5 of the Service Request Enable Register has been set.

Standard Event Status Register and Standard Event Status Enable Register (Continued)

The Standard Event Status Enable Register allows the user to enable any of the Standard Event Status Register reports. The Standard Event Status Enable command (✱ESE) sets the Standard Event Status Enable Register bits. If a bit of this register is set, then that function is enabled. To set a bit, send the command ✱ESE with the bit weighting for each bit you want to be set added together. See the ✱ESE command discussion for further details.

The Standard Event Status Enable Query, ✱ESE?, reads the Standard Event Status Enable Register. ✱ESR? reads the Standard Event Status Register. Once this register has been read, all of the bits are reset to zero.

Power On (PON) Bit (7) – Set to indicate an instrument off-on transition.

Command Error (CME) Bit (5) – If bit 5 is set, a command error has been detected since the last reading. This means that the instrument could not interpret the command due to a syntax error, an unrecognized header, unrecognized terminators, or an unsupported command.

Execution Error (EXE) Bit (4) – If bit 4, the EXE bit is set, an execution error has been detected. This occurs when the instrument is instructed to do something not within its capabilities.

Device Dependent Error (DDE) Bit (3) – A device dependent error has been detected if the DDE bit is set. The actual device dependent error can be found by executing the various device dependent queries.

Query Error (QYE) Bit (2) – The QYE bit indicates a query error. It occurs rarely and involves loss of data because the output queue is full.

Operation Complete (OPC) Bit (0) – This bit is generated in response to the ✱OPC common command. It indicates when the Model 460 has completed all selected pending operations.

4.1.4 IEEE Interface Example Programs

Two BASIC programs are included to illustrate the IEEE-488 communication functions of the instrument. The first program was written in Visual Basic. Refer to Paragraph 4.1.4.1 for instructions on how to setup the program. The Visual Basic code is provided in Table 4-2. The second program is written in Quick Basic. Refer to Paragraph 4.1.4.3 for instructions on how to setup the program. The Quick Basic code is provided in Table 4-3. Finally, a description of operation common to both programs is provided in Paragraph 4.1.4.5. While the hardware and software required to produce and implement these programs not included with the instrument, the concepts illustrated apply to almost any application where these tools are available.

4.1.4.1 IEEE-488 Interface Board Installation for Visual Basic Program

This procedure works for Plug and Play GPIB Hardware and Software for Windows 98/95. This example uses the AT-GPIB/TNT GPIB card.

1. Install the GPIB Plug and Play Software and Hardware using National Instruments instructions.
2. Verify that the following files have been installed to the Windows System folder:
   a. gpib-32.dll
   b. gpib.dll
   c. gpib32ft.dll

   Files b and c will support 16-bit Windows GPIB applications if any are being used.
3. Locate the following files and make note of their location. These files will be used during the development process of a Visual Basic program.
   a. Niglobal.bas
   b. Vbib-32.bas

NOTE: If the files in Steps 2 and 3 are not installed on your computer, they may be copied from your National Instruments setup disks or they may be downloaded from www.ni.com.

4. Configure the GPIB by selecting the System icon in the Windows 98/95 Control Panel located under Settings on the Start Menu. Configure the GPIB Settings as shown in Figure 4-1. Configure the DEV12 Device Template as shown in Figure 4-2. Be sure to check the Readdress box.

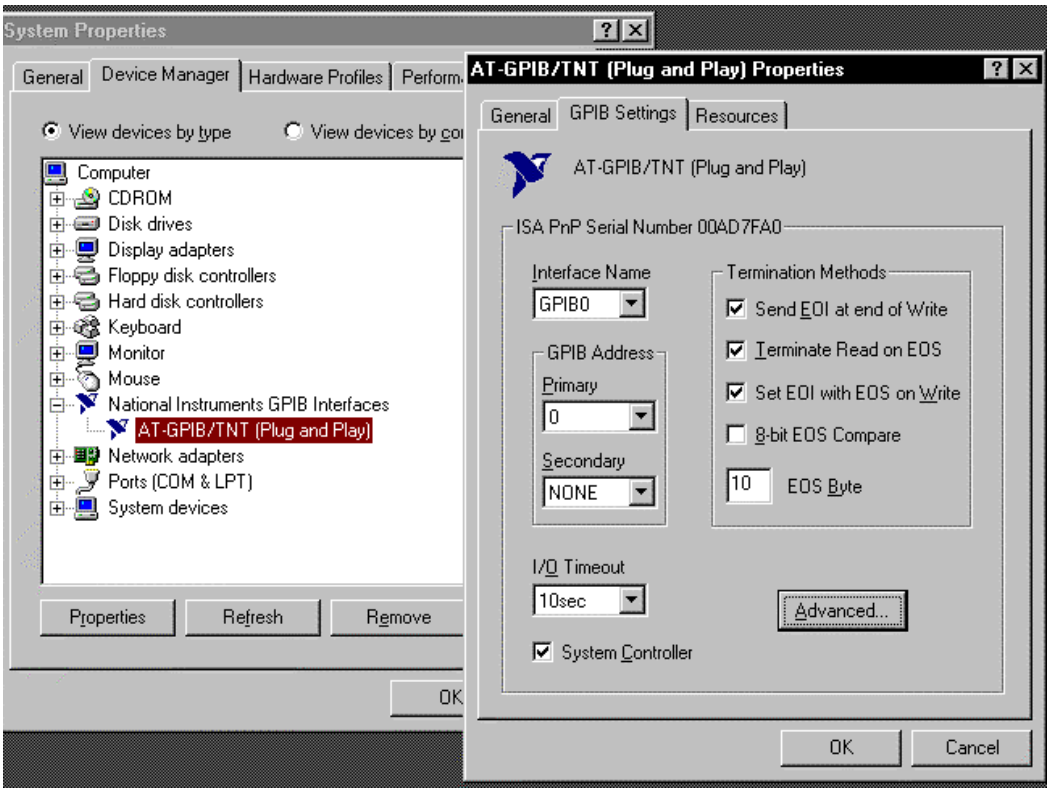


Figure 4-1. GPIB Setting Configuration

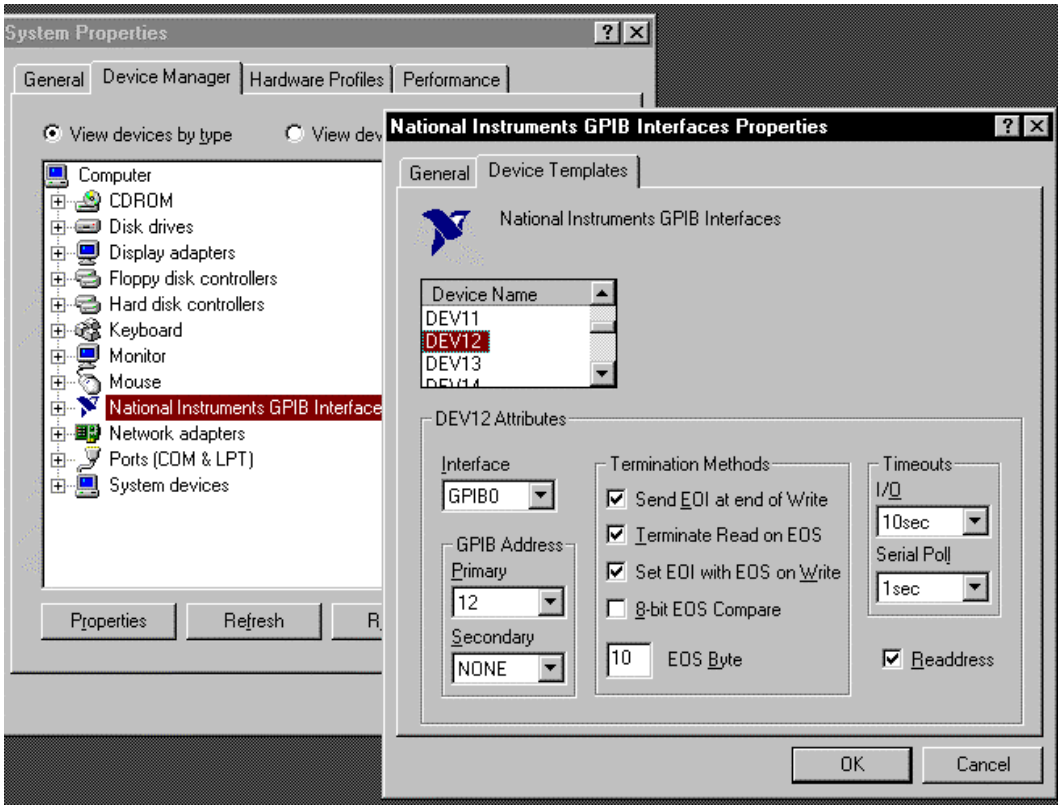
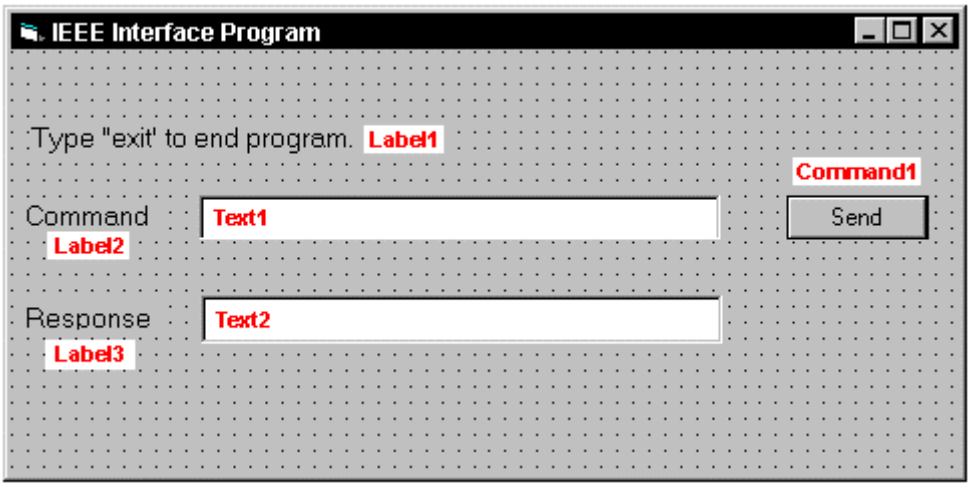


Figure 4-2. DEV 12 Device Template Configuration

4.1.4.2 Visual Basic IEEE-488 Interface Program Setup

This IEEE-488 interface program works with Visual Basic 6.0 (VB6) on an IBM PC (or compatible) with a Pentium-class processor. A Pentium 90 or higher is recommended, running Windows 95 or better. It assumes your IEEE-488 (GPIB) card is installed and operating correctly (refer to Paragraph 4.1.4.1). Use the following procedure to develop the IEEE-488 Interface Program in Visual Basic.

1. Start VB6.
2. Choose Standard EXE and select Open.
3. Resize form window to desired size.
4. On the Project Menu, select Add Module, select the Existing tab, then navigate to the location on your computer to add the following files: Niglobal.bas and Vbib-32.bas.
5. Add controls to form:
   a. Add three Label controls to the form.
   b. Add two TextBox controls to the form.
   c. Add one CommandButton control to the form.
6. On the View Menu, select Properties Window.
7. In the Properties window, use the dropdown list to select between the different controls of the current project.

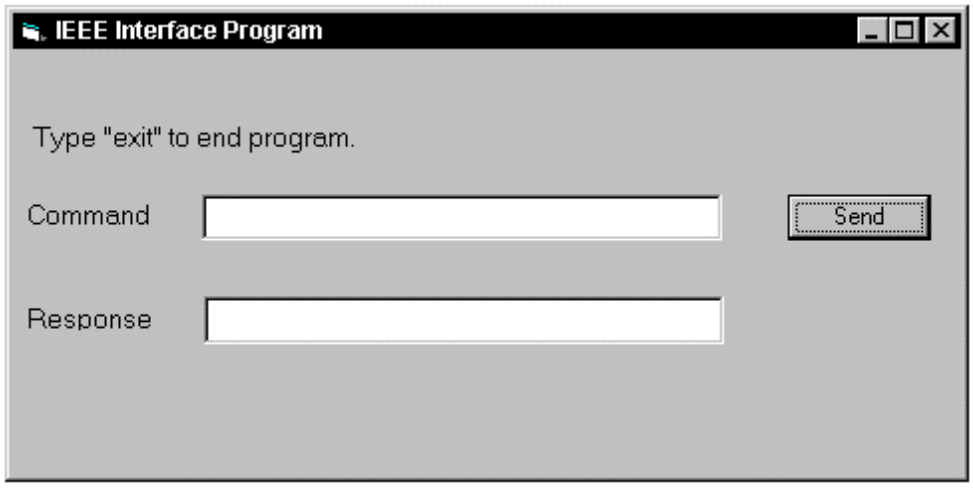


10. Set the properties of the controls as defined in Table 4-1.
11. Save the program.

Table 4-1. IEEE-488 Interface Program Control Properties

Current Name	Property	New Value
Label1	Name Caption	lblExitProgram Type "exit" to end program.
Label2	Name Caption	lblCommand Command
Label3	Name Caption	lblResponse Response
Text1	Name Text	txtCommand <blank>
Text2	Name Text	txtResponse <blank>
Command1	Name Caption Default	cmdSend Send True
Form1	Name Caption	frmIEEE IEEE Interface Program

12. Add code (provided in Table 4-2).
    a. In the Code Editor window, under the Object dropdown list, select (General). Add the statement: Public gSend as Boolean
    b. Double Click on cmdSend. Add code segment under Private Sub cmdSend_Click( ) as shown in Table 4-2.
    c. In the Code Editor window, under the Object dropdown list, select Form. Make sure the Procedure dropdown list is set at Load. The Code window should have written the segment of code: Private Sub Form_Load( ). Add the code to this subroutine as shown in Table 4-2.
13. Save the program.
14. Run the program. The program should resemble the following.



15. Type in a command or query in the Command box as described in Paragraph 4.1.4.5.
16. Press Enter or select the Send button with the mouse to send command.
17. Type Exit and press Enter to quit.

Table 4-2. Visual Basic IEEE-488 Interface Program

```
Public gSend As Boolean                                 'Global used for Send button state
Private Sub cmdSend_Click()                             'Routine to handle Send button press
    gSend = True                                        'Set Flag to True
End Sub
Private Sub Form_Load()                                 'Main code section
    Dim strReturn As String                             'Used to return response
    Dim term As String                                  'Terminators
    Dim strCommand As String                            'Data string sent to instrument
    Dim intDevice As Integer                            'Device number used with IEEE

    frmIEEE.Show                                        'Show main window
    term = Chr(13) & Chr(10)                            'Terminators are <CR><LF>
    strReturn = ""                                      'Clear return string

    Call ibdev(0, 12, 0, T10s, 1, &H140A, intDevice)    'Initialize the IEEE device
    Call ibconfig(intDevice, ibcREADDR,1)               'Setup Repeat Addressing
    Do
        Do                                              'Wait loop
        DoEvents                                        'Give up processor to other events
        Loop Until gSend = True                         'Loop until Send button pressed
        gSend = False                                   'Set Flag as False

        strCommand = frmIEEE.txtCommand.Text            'Get Command
        strReturn = ""                                  'Clear response display

        strCommand = UCase(strCommand)                  'Set all characters to upper case
        If strCommand = "EXIT" Then                     'Get out on EXIT
            End
        End If

        Call ibwrt(intDevice, strCommand & term)        'Send command to instrument
        If (ibsta And EERR) Then                        'Check for IEEE errors
            'do error handling if needed                'Handle errors here
        End If

        If InStr(strCommand, "?") <> 0 Then             'Check to see if query
            strReturn = Space(100)                      'Build empty return buffer
            Call ibrd(intDevice, strReturn)             'Read back response
            If (ibsta And EERR) Then                    'Check for IEEE errors
                'do error handling if needed            'Handle errors here
            End If

            If strReturn <> "" Then                     'Check if empty string
                strReturn = RTrim(strReturn)            'Remove extra spaces and Terminators
                Do While Right(strReturn, 1) = Chr(10) Or Right(strReturn, 1) = Chr(13)
                    strReturn = Left(strReturn, Len(strReturn) - 1)
                Loop
            Else
                strReturn = "No Response"               'Send No Response
            End If

            frmIEEE.txtResponse.Text = strReturn        'Put response in text on main form
        End If
    Loop
End Sub
```

4.1.4.3 IEEE-488 Interface Board Installation for Quick Basic Program

This procedure works on an IBM PC (or compatible) running DOS or in a DOS window. This example uses the National Instruments GPIB-PCII/IIA card.

1. Install GPIB-PCII/IIA card using National Instruments instructions.
2. Install NI-488.2 software (for DOS). Version 2.1.1 was used for the example.
3. Verify that config.sys contains the command: device = \gpib-pc\gpib.com.
4. Reboot the computer.
5. Run IBTEST to test software configuration. Do not install the instrument before running IBTEST.
6. Run IBCONF to configure the GPIB – PCII/IIA board and dev 12. Set the EOS byte to 0AH and Enable Repeat Addressing to Yes. See Figure 4-3. IBCONF modifies gpib.com.
7. Connect the instrument to the interface board and power up the instrument. Verify the address is 12 and terminators are CR LF.

4.1.4.4 Quick Basic Program

The IEEE-488 interface program in Table 4-3 works with QuickBasic 4.0/4.5 or Qbasic on an IBM PC (or compatible) running DOS or in a DOS window. It assumes your IEEE-488 (GPIB) card is installed and operating correctly (refer to Paragraph 4.1.4.3). Use the following procedure to develop the Serial Interface Program in Quick Basic.

1. Copy c:\gpib-pc\Qbasic\qbib.obj to the QuickBasic directory (QB4).
2. Change to the QuickBasic directory and type: link /q qbib.obj,,,bqlb4x.lib; where x = 0 for QB4.0 and 5 for QB4.5 This one-time only command produces the library file qbib.qlb. The procedure is found in the National Instruments QuickBasic readme file Readme.qb.
3. Start QuickBasic. Type: qb /l qbib.qlb. Start QuickBasic in this way each time the IEEE interface is used to link in the library file.
4. Create the IEEE example interface program in QuickBasic. Enter the program exactly as presented in Table 4-3. Name the file "ieeeexam.bas" and save.
5. Run the program.
6. Type a command query as described in Paragraph 4.1.4.5.
7. Type "EXIT" to quit the program.

```
National Instruments          GPIB0 Configuration       GPIB-PC2/2A Ver 2.1

Primary GPIB Address ........ →0
Secondary GPIB Address ...... NONE
Timeout setting ............. 10sec

Terminate Read on EOS ....... Yes
Set EOI with EOS on Writes .. Yes
Type of compare on EOS ...... 7-Bit
EOS byte .................... 0Ah
Send EOI at end of Write .... Yes

System Controller ........... Yes
Assert REN when SC .......... No
Enable Auto Serial Polling .. No
Enable CIC Protocol ......... No
Bus Timing .................. 500nsec
Parallel Poll Duration ...... Default

Use this GPIB board ......... Yes
Board Type .................. PCII
Base I/O Address ............ 02B8h

Select the primary GPIB address by
using the left and right arrow keys.

This address is used to compute the
talk and listen addresses which
identify the board or device on the
GPIB. Valid primary addresses range
from 0 to 30 (00H to 1EH).

* Adding 32 to the primary address
  forms the Listen Address (LA).
* Adding 64 to the primary address
  forms the Talk Address (TA).

EXAMPLE: Selecting a primary address
of 10 yields the following:

  10 + 32 = 42   (Listen address)
  10 + 64 = 74   (Talk address)

F1: Help  F6: Reset Value  F9/Esc: Return to Map  Ctl PgUp/PgDn: Next/Prev Board
```

```
National Instruments          DEV12 Configuration       GPIB-PC2/2A Ver 2.1

Primary GPIB Address ........ →12
Secondary GPIB Address ...... NONE
Timeout setting ............. 10sec
Serial Poll Timeout ......... 1sec

Terminate Read on EOS ....... Yes
Set EOI with EOS on Writes .. Yes
Type of compare on EOS ...... 7-Bit
EOS byte .................... 0Ah
Send EOI at end of Write .... Yes

Enable Repeat Addressing .... Yes

Select the primary GPIB address by
using the left and right arrow keys.

This address is used to compute the
talk and listen addresses which
identify the board or device on the
GPIB. Valid primary addresses range
from 0 to 30 (00H to 1EH).

* Adding 32 to the primary address
  forms the Listen Address (LA).
* Adding 64 to the primary address
  forms the Talk Address (TA).

EXAMPLE: Selecting a primary address
of 10 yields the following:

  10 + 32 = 42   (Listen address)
  10 + 64 = 74   (Talk address)

F1: Help  F6: Reset Value  F9/Esc: Return to Map  Ctl PgUp/PgDn: Next/Prev Board
```

IBCONF.EXE.eps

Figure 4-3. Typical National Instruments GPIB Configuration from IBCONF.EXE

Table 4-3. Quick Basic IEEE-488 Interface Program

```
'       IEEEEXAM.BAS    EXAMPLE PROGRAM FOR IEEE-488 INTERFACE
'
'       This program works with QuickBasic 4.0/4.5 on an IBM PC or compatible.
'
'       The example requires a properly configured National Instruments GPIB-PC2 card. The REM
'       $INCLUDE statement is necessary along with a correct path to the file QBDECL.BAS.
'       CONFIG.SYS must call GPIB.COM created by IBCONF.EXE prior to running Basic. There must
'       be QBIB.QBL library in the QuickBasic Directory and QuickBasic must start with a link
'       to it. All instrument settings are assumed to be defaults: Address 12, Terminators
'       <CR> <LF> and EOI active.
'
'       To use, type an instrument command or query at the prompt. The computer transmits to
'       the instrument and displays any response. If no query is sent, the instrument responds
'       to the last query received. Type "EXIT" to exit the program.
'
       REM $INCLUDE: 'c:\gpib-pc\qbasic\qbdecl.bas'         'Link to IEEE calls
       CLS                                                  'Clear screen
       PRINT "IEEE-488 COMMUNICATION PROGRAM"
       PRINT

       CALL IBFIND("dev12", DEV12%)                         'Open communication at address 12
       TERM$ = CHR$(13) + CHR$(10)                          'Terminators are <CR><LF>

LOOP2: IN$ = SPACE$(2000)                                   'Clear for return string

       LINE INPUT "ENTER COMMAND (or EXIT):"; CMD$          'Get command from keyboard
       CMD$ = UCASE$(CMD$)                                  'Change input to upper case
          IF CMD$ = "EXIT" THEN END                         'Get out on Exit
       CMD$ = CMD$ + TERM$

       CALL IBWRT(DEV12%, CMD$)                             'Send command to instrument

       CALL IBRD(DEV12%, IN$)                               'Get data back each time

       ENDTEST = INSTR(IN$, CHR$(13))                       'Test for returned string
          IF ENDTEST > 0 THEN                               'String is present if <CR> is seen
             IN$ = MID$(IN$, 1, ENDTEST - 1)                'Strip off terminators
             PRINT "RESPONSE:", IN$                         'Print return string
          ELSE
             PRINT "NO RESPONSE"                            'No string present if timeout
          END IF
       GOTO LOOP2                                           'Get next command
```

4.1.4.5 Program Operation

Once either example program is running, try the following commands and observe the response of the instrument. Input from the user is shown in **bold** and terminators are added by the program. The word [term] indicates the required terminators included with the response.

`ENTER COMMAND? **\*IDN?**`	Identification query. Instrument will return a string identifying itself.
`RESPONSE: LSCI,MODEL450,0,020303[term]`	
`ENTER COMMAND? **FIELD?**`	Field reading query. Instrument will return a string with the present field reading.
`RESPONSE: +12.345[term]`	
`ENTER COMMAND? **FIELDM?**`	Field multiplier query. Instrument will return a string with the field units multiplier. Blank indicated gauss, k indicates kilo gauss, etc.
`RESPONSE: k[term]`	
`ENTER COMMAND? **RANGE 0**`	Range command. Instrument will change the field range to the highest setting. No response will be sent.
`ENTER COMMAND? **RANGE?**`	Range query. Instrument will return a string with the present range setting.
`RESPONSE: 0[term]`	

The following are additional notes on using either IEEE-488 Interface program.

- If you enter a correctly spelled query without a "**?**," nothing will be returned. Incorrectly spelled commands and queries are ignored. Commands and queries and should have a space separating the command and associated parameters.
- Leading zeros and zeros following a decimal point are not needed in a command string, but are sent in response to a query. A leading "+" is not required but a leading "–" *is* required.

4.1.5 Troubleshooting

New Installation

1. Check instrument address.
2. Always send terminators.
3. Send entire message string at one time including terminators.
4. Send only one simple command at a time until communication is established.
5. Be sure to spell commands correctly and use proper syntax.
6. Attempt both 'Talk' and 'Listen' functions. If one works but not the other, the hardware connection is working, so look at syntax, terminators, and command format.
7. If only one message is received after resetting the interface, check the "repeat addressing" setting. It should be enabled.

Old Installation No Longer Working

1. Power instrument off then on again to see if it is a soft failure.
2. Power computer off then on again to see if the IEEE card is locked up.
3. Verify that the address has not been changed on the instrument during a memory reset.
4. Check all cable connections.

Intermittent Lockups

1. Check cable connections and length.
2. Increase delay between commands to 50 ms to make sure instrument is not being over loaded.

4.2 SERIAL INTERFACE OVERVIEW

The serial interface used in the Model 460 is commonly referred to as an RS-232C interface. RS-232C is a standard of the Electronics Industries Association (EIA) that describes one of the most common interfaces between computers and electronic equipment. The RS-232C standard is quite flexible and allows many different configurations. However, any two devices claiming RS-232C compatibility cannot necessarily be plugged together without interface setup. The remainder of this paragraph briefly describes the key features of a serial interface that are supported by the instrument. A customer supplied computer with similarly configured interface port is required to enable communication.

4.2.1 Physical Connection

The Model 460 has an RJ-11 connector on the rear panel for serial communication. The original RS-232C standard specifies 25 pins, but 9-pin, 25-pin, and RJ-11 connectors are commonly used in the computer industry. For you convenience, Lake Shore offers a Model 4001 RJ-11 Cable. When combined with either the Model 4002 DB-25 Adapter or Model 4003 DE-9 Adapter, this cable assembly can be used to connect the instrument to a computer with the corresponding connector type. These adapters are described in Chapter 5 – Accessories and Probes and are schematically diagramed in Figures 6-6 thru 6-8.

Equipment with Data Communications Equipment (DCE) wiring can be connected to the instrument with a straight through cable. However, if the interface is for Data Terminal Equipment (DTE), a Null Modem Adapter is required to exchange the transmit (TxD) and receive (RxD) lines.

The instrument uses drivers to generate the transmission voltage levels required by the RS-232C standard. These voltages are considered safe under normal operating conditions because of their relatively low voltage and current limits. The drivers are designed to work with cables up to 50 feet in length.

To maintain Electromagnetic Compatibility (EMC), add the clamp-on ferrite filter (P/N 109-053) included with the connector kit to the Serial Interface cable near the instrument rear panel when that interface is used.

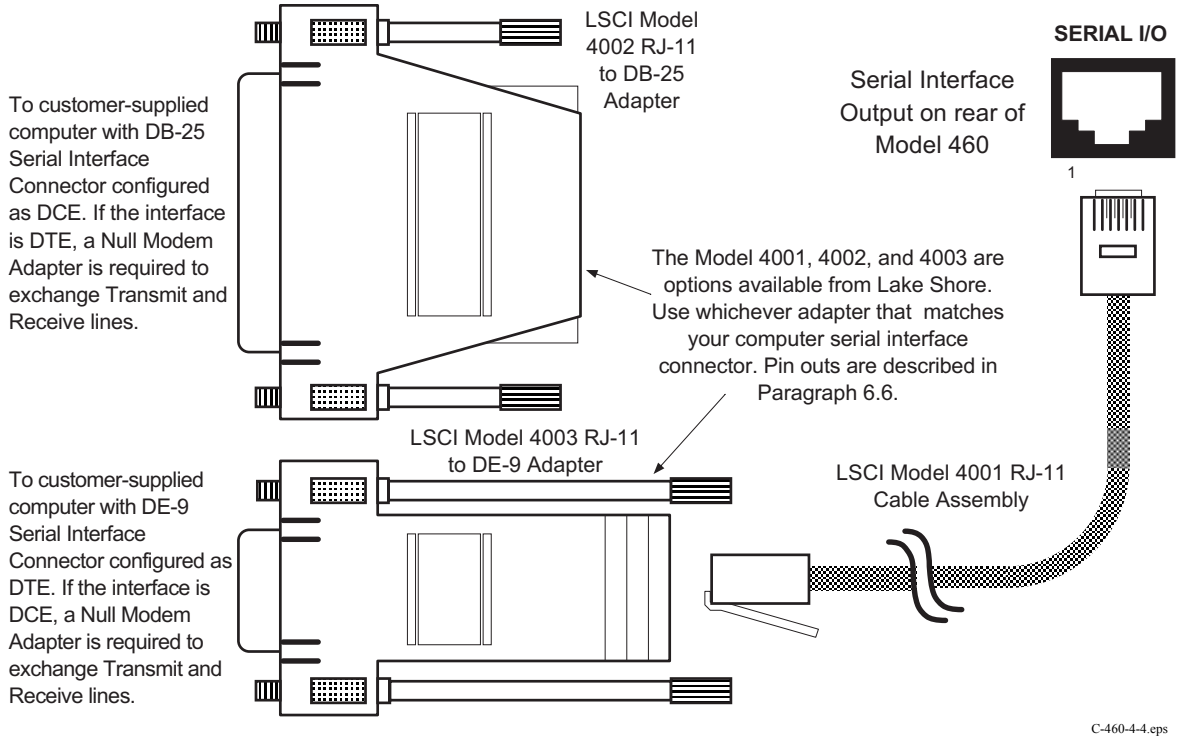

LSCI Model 4002 RJ-11 to DB-25 Adapter
SERIAL I/O
Serial Interface Output on rear of Model 460
1
To customer-supplied computer with DB-25 Serial Interface Connector configured as DCE. If the interface is DTE, a Null Modem Adapter is required to exchange Transmit and Receive lines.
The Model 4001, 4002, and 4003 are options available from Lake Shore. Use whichever adapter that matches your computer serial interface connector. Pin outs are described in Paragraph 6.6.
LSCI Model 4003 RJ-11 to DE-9 Adapter
LSCI Model 4001 RJ-11 Cable Assembly
To customer-supplied computer with DE-9 Serial Interface Connector configured as DTE. If the interface is DCE, a Null Modem Adapter is required to exchange Transmit and Receive lines.
C-460-4-4.eps

Figure 4-4. Serial Interface Adapters

4.2.2 Hardware Support

The Model 460 interface hardware supports the following features. Asynchronous timing is used for the individual bit data within a character. This timing requires start and stop bits as part of each character so the transmitter and receiver can resynchronized between each character. Half duplex transmission allows the instrument to be either a transmitter or a receiver of data but not at the same time. Communication speeds of 300, 1200 or 9600 baud are supported. The Baud rate is the only interface parameter that can be changed by the user.

Hardware handshaking is not supported by the instrument. Handshaking is often used to guarantee that data message strings do not collide and that no data is transmitted before the receiver is ready. In this instrument appropriate software timing substitutes for hardware handshaking. User programs must take full responsibility for flow control and timing as described in Paragraph 4.2.5.

4.2.3 Character Format

A character is the smallest piece of information that can be transmitted by the interface. Each character is 10 bits long and contains data bits, bits for character timing and an error detection bit. The instrument uses 7 bits for data in the ASCII format. One start bit and one stop bit are necessary to synchronize consecutive characters. Parity is a method of error detection. One parity bit configured for odd parity is included in each character.

ASCII letter and number characters are used most often as character data. Punctuation characters are used as delimiters to separate different commands or pieces of data. Two special ASCII characters, carriage return (CR 0DH) and line feed (LF 0AH), are used to indicate the end of a message string.

Table 4-4. Serial Interface Specifications

Connector Type:	RJ-11 Connector
Connector Wiring:	DTE
Voltage Levels:	EIA RS-232C Specified
Transmission Distance:	50 feet maximum
Timing Format:	Asynchronous
Transmission Mode:	Half Duplex
Baud Rate:	300, 1200, 9600
Handshake:	Software timing
Character Bits:	1 Start, 7 Data, 1 Parity, 1 Stop
Parity:	Odd
Terminators:	CR(0DH) LF(0AH)
Command Rate:	20 commands per second maximum

4.2.4 Message Strings

A message string is a group of characters assembled to perform an interface function. There are three types of message strings commands, queries and responses. The computer issues command and query strings through user programs, the instrument issues responses. Two or more command strings can be chained together in one communication but they must be separated by a semi-colon (;). Only one query is permitted per communication but it can be chained to the end of a command. The total communication string must not exceed 64 characters in length.

A command string is issued by the computer and instructs the instrument to perform a function or change a parameter setting. The format is:

<command mnemonic><space><parameter data><terminators>.

Command mnemonics and parameter data necessary for each one is described in Paragraph 4.3. Terminators must be sent with every message string.

Message Strings (Continued)

A query string is issued by the computer and instructs the instrument to send a response. The query format is:

<query mnemonic><?><space><parameter data><terminators>.

Query mnemonics are often the same as commands with the addition of a question mark. Parameter data is often unnecessary when sending queries. Query mnemonics and parameter data if necessary is described in Paragraph 4.3. Terminators must be sent with every message string. The computer should expect a response very soon after a query is sent.

A response string is the instruments response or answer to a query string. The instrument will respond only to the last query it receives. The response can be a reading value, status report or the present value of a parameter. Response data formats are listed along with the associated queries in Paragraph 4.3. The response is sent as soon as possible after the instrument receives the query. Typically it takes 10 ms for the instrument to begin the response. Some responses take longer.

4.2.5 Message Flow Control

It is important to remember that the user program is in charge of the serial communication at all times. The instrument can not initiate communication, determine which device should be transmitting at a given time or guarantee timing between messages. All of this is the responsibility of the user program.

When issuing commands only the user program should:

- Properly format and transmit the command including terminators as one string.
- Guarantee that no other communication is started for 50 ms after the last character is transmitted.
- Not initiate communication more than 20 times per second.

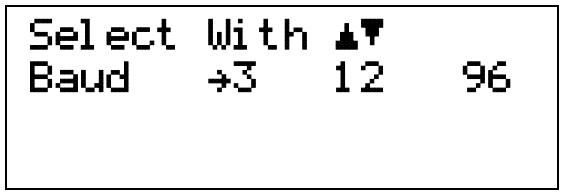
When issuing queries or queries and commands together the user program should:

- Properly format and transmit the query including terminators as one string.
- Prepare to receive a response immediately.
- Receive the entire response from the instrument including the terminators.
- Guarantee that no other communication is started during the response or for 50 ms after it completes.
- Not initiate communication more than 20 times per second.

Failure to follow these simple rules will result in inability to establish communication with the instrument or intermittent failures in communication.

4.2.6 Changing Baud Rate

To use the Serial Interface, you must first set the Baud rate. Press **Interface** key to display the following screen.



Press the ▲ or ▼ keys to cycle through the choices of 300, 1200, or 9600 Baud. The rate selected will have a right pointing arrow (→) immediately to the left. Press **Enter** to accept the new number.

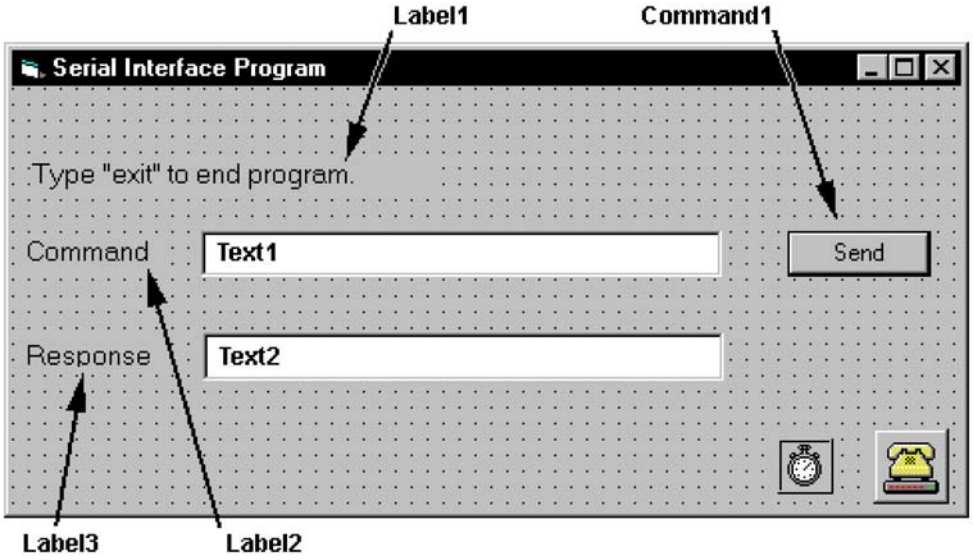
4.2.7 Serial Interface Basic Programs

Two BASIC programs are included to illustrate the serial communication functions of the instrument. The first program was written in Visual Basic. Refer to Paragraph 4.2.7.1 for instructions on how to setup the program. The Visual Basic code is provided in Table 4-4. The second program was written in Quick Basic. Refer to Paragraph 4.2.7.2 for instructions on how to setup the program. The Quick Basic code is provided in Table 4-5. Finally, a description of operation common to both programs is provided in Paragraph 4.2.7.3. While the hardware and software required to produce and implement these programs not included with the instrument, the concepts illustrated apply to almost any application where these tools are available.

4.2.7.1 Visual Basic Serial Interface Program Setup

The serial interface program (Table 4-5) works with Visual Basic 6.0 (VB6) on an IBM PC (or compatible) with a Pentium-class processor. A Pentium 90 or higher is recommended, running Windows 95 or better, with a serial interface. It uses the COM1 communications port at 9600 Baud. Use the following procedure to develop the Serial Interface Program in Visual Basic.

1. Start VB6.
2. Choose Standard EXE and select Open.
3. Resize form window to desired size.
4. On the Project Menu, click Components to bring up a list of additional controls available in VB6.
5. Scroll through the controls and select Microsoft Comm Control 6.0. Select OK. In the toolbar at the left of the screen, the Comm Control will have appeared as a telephone icon.
6. Select the Comm control and add it to the form.
7. Add controls to form:
   a. Add three Label controls to the form.
   b. Add two TextBox controls to the form.
   c. Add one CommandButton control to the form.
   d. Add one Timer control to the form.
8. On the View Menu, select Properties Window.
9. In the Properties window, use the dropdown list to select between the different controls of the current project.

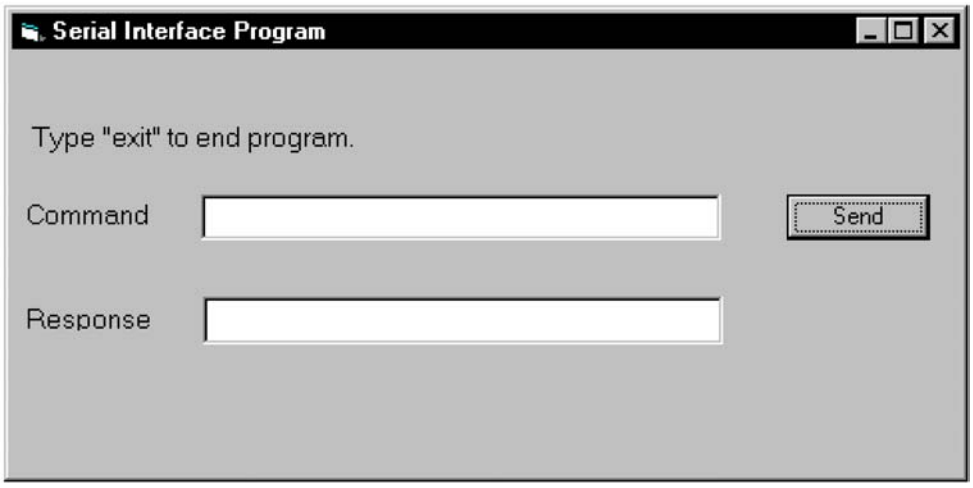


10. Set the properties of the controls as defined in Table 4-5.
11. Save the program.

Table 4-5. Serial Interface Program Control Properties

Current Name	Property	New Value
Label1	Name Caption	lblExitProgram Type "exit" to end program.
Label2	Name Caption	lblCommand Command
Label3	Name Caption	lblResponse Response
Text1	Name Text	txtCommand <blank>
Text2	Name Text	txtResponse <blank>
Command1	Name Caption Default	cmdSend Send True
Form1	Name Caption	frmSerial Serial Interface Program
Timer1	Enabled Interval	False 10

12. Add code (provided in Table 4-6).
    a. In the Code Editor window, under the Object dropdown list, select (General). Add the statement: Public gSend as Boolean
    b. Double Click on cmdSend. Add code segment under Private Sub cmdSend_Click( ) as shown in Table 4-6.
    c. In the Code Editor window, under the Object dropdown list, select Form. Make sure the Procedure dropdown list is set at Load. The Code window should have written the segment of code: Private Sub Form_Load( ). Add the code to this subroutine as shown in Table 4-6.
    d. Double Click on the Timer control. Add code segment under Private Sub Timer1_Timer() as shown in Table 4-6.
    e. Make adjustments to code if different Com port settings are being used.
13. Save the program.
14. Run the program. The program should resemble the following.



15. Type in a command or query in the Command box as described in Paragraph 4.2.7.3.
16. Press Enter or select the Send button with the mouse to send command.
17. Type Exit and press Enter to quit.

Table 4-6. Visual Basic Serial Interface Program

```
Public gSend As Boolean                                 'Global used for Send button state

Private Sub cmdSend_Click()                             'Routine to handle Send button press
    gSend = True                                        'Set Flag to True
End Sub

Private Sub Form_Load()                                 'Main code section
    Dim strReturn As String                             'Used to return response
    Dim strHold As String                               'Temporary character space
    Dim Term As String                                  'Terminators
    Dim ZeroCount As Integer                            'Counter used for Timing out
    Dim strCommand As String                            'Data string sent to instrument

    frmSerial.Show                                      'Show main window
    Term = Chr(13) & Chr(10)                            'Terminators are <CR><LF>
    ZeroCount = 0                                       'Initialize counter
    strReturn = ""                                      'Clear return string
    strHold = ""                                        'Clear holding string
    If frmSerial.MSComm1.PortOpen = True Then           'Close serial port to change settings
        frmSerial.MSComm1.PortOpen = False
    End If
    frmSerial.MSComm1.CommPort = 1                      'Example of Comm 1
    frmSerial.MSComm1.Settings = "9600,o,7,1"           'Example of 9600 Baud,Parity,Data,Stop
    frmSerial.MSComm1.InputLen = 1                      'Read one character at a time
    frmSerial.MSComm1.PortOpen = True                   'Open port

  Do
    Do                                                  'Wait loop
    DoEvents                                            'Give up processor to other events
    Loop Until gSend = True                             'Loop until Send button pressed
    gSend = False                                       'Set Flag as false

    strCommand = frmSerial.txtCommand.Text              'Get Command
    strReturn = ""                                      'Clear response display

    strCommand = UCase(strCommand)                      'Set all characters to upper case
    If strCommand = "EXIT" Then                         'Get out on EXIT
        End
    End If

    frmSerial.MSComm1.Output = strCommand & Term        'Send command to instrument
    If InStr(strCommand, "?") <> 0 Then                 'Check to see if query
        While (ZeroCount < 20) And (strHold <> Chr$(10))  'Wait for response
            If frmSerial.MSComm1.InBufferCount = 0 Then   'Add 1 to timeout if no character
                frmSerial.Timer1.Enabled = True
                Do
                DoEvents                                'Wait for 10 millisecond timer
                Loop Until frmSerial.Timer1.Enabled = False
                ZeroCount = ZeroCount + 1               'Timeout at 2 seconds
            Else
                ZeroCount = 0                           'Reset timeout for each character
                strHold = frmSerial.MSComm1.Input       'Read in one character
                strReturn = strReturn + strHold         'Add next character to string
            End If
        Wend                                            'Get characters until terminators

        If strReturn <> "" Then                         'Check if string empty
            strReturn = Mid(strReturn, 1, InStr(strReturn, Term) - 1)  'Strip terminators
        Else
            strReturn = "No Response"                   'Send No Response
        End If
        frmSerial.txtResponse.Text = strReturn          'Put response in textbox on main form
        strHold = ""                                    'Reset holding string
        ZeroCount = 0                                   'Reset timeout counter
    End If
  Loop
End Sub

Private Sub Timer1_Timer()                              'Routine to handle Timer interrupt
    frmSerial.Timer1.Enabled = False                    'Turn off timer
End Sub
```

4.2.7.2 Quick Basic Serial Interface Program Setup

The serial interface program (Table 4-7) works with QuickBasic 4.0/4.5 or Qbasic on an IBM PC (or compatible) running DOS or in a DOS window with a serial interface. It uses the COM1 communication port at 9600 Baud. Use the following procedure to develop the Serial Interface Program in Quick Basic.

1. Start the Basic program.
2. Enter the program exactly as presented in Table 4-7.
3. Adjust the Com port and Baud rate in the program as necessary.
4. Lengthen the "TIMEOUT" count if necessary.
5. Save the program.
6. Run the program.
7. Type a command query as described in Paragraph 4.2.7.3.
8. Type "EXIT" to quit the program.

Table 4-7. Quick Basic Serial Interface Program

```
      CLS                                              'Clear screen
      PRINT " SERIAL COMMUNICATION PROGRAM"
      PRINT
      TIMEOUT = 2000                                   'Read timeout (may need more)
      BAUD$ = "9600"
      TERM$ = CHR$(13) + CHR$(10)                      'Terminators are <CR><LF>
      OPEN "COM1:" + BAUD$ + ",O,7,1,RS" FOR RANDOM AS #1 LEN = 256

LOOP1: LINE INPUT "ENTER COMMAND (or EXIT):"; CMD$     'Get command from keyboard
      CMD$ = UCASE$(CMD$)                              'Change input to upper case
         IF CMD$ = "EXIT" THEN CLOSE #1: END           'Get out on Exit
      CMD$ = CMD$ + TERM$
      PRINT #1, CMD$;                                  'Send command to instrument

      IF INSTR(CMD$, "?") <> 0 THEN                    'Test for query
         RS$ = ""                                      'If query, read response
         N = 0                                         'Clr return string and count

         WHILE (N < TIMEOUT) AND (INSTR(RS$, TERM$) = 0)    'Wait for response
            IN$ = INPUT$(LOC(1), #1)                   'Get one character at a time
            IF IN$ = "" THEN N = N + 1 ELSE N = 0      'Add 1 to timeout if no chr
            RS$ = RS$ + IN$                            'Add next chr to string
         WEND                                          'Get chrs until terminators

         IF RS$ <> "" THEN                             'See if return string is empty
            RS$ = MID$(RS$, 1, (INSTR(RS$, TERM$) - 1))'Strip off terminators
            PRINT "RESPONSE:"; RS$                     'Print response to query
         ELSE
            PRINT "NO RESPONSE"                        'No response to query
         END IF
      END IF                                           'Get next command
      GOTO LOOP1
```

4.2.7.3 Program Operation

Once either program is running, try the following commands and observe the response of the instrument. Input from the user is shown in **bold** and terminators are added by the program. The word [term] indicates the required terminators included with the response.

`ENTER COMMAND? **\*IDN?**`	Identification query. Instrument will return a string identifying itself.
`RESPONSE: LSCI,MODEL460,0,070199[term]`	
`ENTER COMMAND? **FIELD?**`	Field reading query. Instrument will return a string with the present field reading.
`RESPONSE: +12.345[term]`	
`ENTER COMMAND? **FIELDM?**`	Field multiplier query. Instrument will return a string with the field units multiplier. Blank indicated gauss, k indicates kilo gauss, etc.
`RESPONSE: k[term]`	
`ENTER COMMAND? **RANGE 0**`	Range command. Instrument will change the field range to the highest setting. No response will be sent.
`ENTER COMMAND? **RANGE?**`	Range query. Instrument will return a string with the present range setting.
`RESPONSE: 0[term]`	
`ENTER COMMAND? **RANGE 0;RANGE?**`	Range command followed by range query. Instrument will change range to highest setting then return a string with the present range setting.
`RESPONSE: 0[term]`	

The following are additional notes on using either Serial Interface program.

- If you enter a correctly spelled query without a "**?**," nothing will be returned. Incorrectly spelled commands and queries are ignored. Commands and queries and should have a space separating the command and associated parameters.
- Leading zeros and zeros following a decimal point are not needed in a command string, but they will be sent in response to a query. A leading "**+**" is not required but a leading "**–**" *is* required.

4.2.8 Trouble Shooting

New Installation

8. Check instrument baud rate
9. Make sure transmit (TD) signal line from the instrument is routed to receive (RD) on the computer and vice versa. (Use a null modem adapter if not).
10. Always send terminators
11. Send entire message string at one time including terminators. (Many terminal emulation programs do not.)
12. Send only one simple command at a time until communication is established.
13. Be sure to spell commands correctly and use proper syntax.

Old Installation No Longer Working

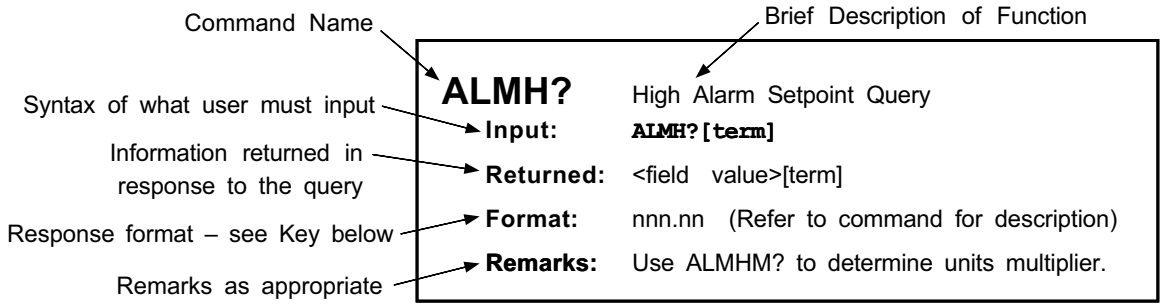
5. Power instrument off then on again to see if it is a soft failure.
6. Power computer off then on again to see if communication port is locked up.
7. Verify that baud rate has not been changed on the instrument during a memory reset.
8. Check all cable connections.

Intermittent Lockups

3. Check cable connections and length.
4. Increase delay between all commands to 100 ms to make sure instrument is not being over loaded.

4.3 COMMAND SUMMARY

This paragraph provides a summary of the IEEE-488 and Serial Interface Commands. The summary is divided into four command groups: common commands are detailed in Paragraph 4.3.1, interface commands in Paragraph 4.3.2, device specific commands in Paragraph 4.3.3, and probe commands in Paragraph 4.3.4. A summary of all commands is provided in Table 4-8.



Key:

*	Begins common interface command.
?	Required to identify queries.
aa…	String of alpha numeric characters.
nn…	String of number characters.
[term]	Terminator characters.
<…>	Indicated a parameter field, many are command specific.
<state>	Parameter field with only On/Off or Enable/Disable states.
<field value>	Field values have the range and resolution of displayed field readings. Field queries must be used with associated multiplier and units queries to obtain a complete field reading. Spaces will be returned in place of unused digits.
<multiplier>	u = micro = 10^{-6}, m = milli = 10^{-3}, (blank) = unity, k = kilo = 10^{3}.

Table 4-8. Command Summary

Command	Function	Page
Common Commands		
✱CLS	Clear Interface Cmd	4-24
✱ESE	Std. Event Status Cmd	4-24
✱ESE?	Std. Event Status Query	4-24
✱ESR?	Std. Event Register Query	4-24
✱IDN?	Identification Query	4-24
✱OPC	Operation Complete Cmd	4-25
✱OPC?	Operation Complete Query	4-25
✱RST	Reset Instrument Cmd	4-25
✱SRE	Service Request Enable Cmd	4-25
✱SRE?	Service Request Enable Query	4-25
✱STB?	Status Byte Query	4-25
✱TST?	Self-Test Query	4-26
✱WAI	Wait-To-Continue Cmd	4-26
Interface Commands		
ADDR	IEEE Address Cmd	4-27
ADDR?	IEEE Address Query	4-27
BAUD	Serial Interface Baud Rate Cmd	4-27
BAUD?	Serial Interface Baud Rate Query	4-27
BRIGT	Display Brightness Cmd	4-27
BRIGT?	Display Brightness Query	4-27
CODE	Keyboard Lock Code Cmd	4-27
CODE?	Keyboard Lock Code Query	4-27
END	EOI Status Cmd	4-28
END?	EOI Status Query	4-28
FAST	Fast Data Mode Cmd	4-28
FAST?	Fast Data Mode Query	4-28
KEY?	Key Pressed Query	4-28
LOCK	Keyboard Lock Cmd	4-28
LOCK?	Keyboard Lock Query	4-28
MODE	Local/Remote Mode Cmd	4-29
MODE?	Local/Remote Mode Query	4-29
SLEEP	Current Source Cmd	4-29
SLEEP?	Current Source Query	4-29
TERM	Terminator Cmd	4-29
TERM?	Terminator Query	4-29
Device Specific Commands		
ACDC	AC/DC Field Reading Cmd	4-30
ACDC?	AC/DC Field Reading Query	4-30
ALARM	Alarm Function On/Off Cmd	4-30
ALARM?	Alarm Function On/Off Query	4-30
ALLF?	All Fields Query	4-30
ALMB	Audible Alarm Cmd	4-30
ALMB?	Audible Alarm Query	4-30
ALMH	Alarm High Point Cmd	4-31
ALMH?	Alarm High Point Query	4-31
ALMHM?	Alarm High Point Multiplier Query	4-31
ALMIO	Alarm Inside/Outside Cmd	4-31
ALMIO?	Alarm Inside/Outside Query	4-31
ALML	Alarm Low Point Cmd	4-31
ALML?	Alarm Low Point Query	4-32
ALMLM?	Alarm Low Point Multiplier Query	4-32
ALMS?	Alarm Status Query	4-32
ANOD	Default Analog Out Cmd	4-32
ANOD?	Default Analog Out Query	4-32
ANOH	Analog Out High Setpoint Cmd	4-32
ANOH?	Analog Out High Setpoint Query	4-33
ANOHM?	Analog Out High Setpoint Multiplier	4-33
ANOL	Analog Out Low Setpoint Cmd	4-33
ANOL?	Analog Out Low Setpoint Query	4-33
ANOLM?	Analog Out Low Setpoint Multiplier	4-33
ANOS	Corrected Analog Output Cmd	4-33
ANOS?	Corrected Analog Output Query	4-34
AOCON	Analog Output Control Mode Cmd	4-34
AOCON?	Analog Output Control Mode Query	4-34
AUTO	Auto Range Cmd	4-34
AUTO?	Auto Range Query	4-34
CHNL	Channel Command	4-34
CHNL?	Channel Query	4-34
FIELD?	Field Reading Query	4-35
FIELDM?	Field Multiplier Query	4-35
FILT	Display Filter Cmd	4-35
FILT?	Display Filter Query	4-35
FNUM	Display Filter Points Cmd	4-35
FNUM?	Display Filter Points Query	4-35
FWIN	Display Filter Window Cmd	4-36
FWIN?	Display Filter Window Query	4-36
MAX	Max Hold Cmd	4-36
MAX?	Max Hold Query	4-36
MAXC	Max Clear (Reset) Cmd	4-36
MAXR?	Max Reading Query	4-36
MAXRM?	Max Reading Multiplier Query	4-37
PRMS	Peak/RMS Field Cmd	4-37
PRMS?	Peak/RMS Field Query	4-37
RANGE	Manual Range Cmd	4-37
RANGE?	Manual Range Query	4-37
REL	Relative Mode Cmd	4-37
REL?	Relative Mode Query	4-38
RELR?	Relative Mode Reading Query	4-38
RELRM?	Relative Mode Multiplier Query	4-38
RELS	Relative Mode Setpoint Cmd	4-38
RELS?	Relative Mode Setpoint Query	4-38
RELSM?	Relative Mode Setpoint Multiplier	4-38
UNIT	Gauss/Tesla Units Cmd	4-39
UNIT?	Gauss/Tesla Units Query	4-39
VSRC	Vector Magnitude Source Cmd	4-39
VSRC?	Vector Magnitude Source Query	4-39
Probe Commands		
FCOMP	Field Compensation Cmd	4-39
FCOMP?	Field Compensation Query	4-39
ONOFF	Probe On/Off Cmd	4-39
ONOFF?	Probe On/Off Query	4-40
SNUM?	Probe Serial Number Query	4-40
TCOMP	Temp Compensation Cmd	4-40
TCOMP?	Temp Compensation Query	4-40
TYPE?	Probe Type Query	4-40
ZCAL	Zero Probe Cmd	4-40

4.3.1 Common Commands

✱CLS Clear Interface Command

Input: **✱CLS[term]**

Remarks: Clears the bits in the Status Byte Register and Standard Event Status Register and terminates all pending operations. Clears the interface, but *not* the controller. The related controller command is **✱RST**.

✱ESE Configure Event Status Enable Register

Input: **✱ESE <bit weighting>[term]**

Format: nnn[term]

Remarks: Each bit is assigned a bit weighting and represents the enable/disable mask of the corresponding event flag bit in the Standard Event Status Register. To enable an event flag bit, send the command **✱ESE** with the sum of the bit weighting for each desired bit. Refer to Paragraph 4.1.3.2 for a list of event flags.

Example: To enable event flags 0, 3, 4, and 7, send the command **✱ESE 143[term]**. 143 is the sum of the bit weighting for each bit.

Bit	Bit Weighting	Event Name
0	1	OPC
3	8	DDE
4	16	EXE
7	128	PON
	143	

✱ESE? Event Status Enable Register Query

Input: **✱ESE?[term]**

Returned: <bit weighting>

Format: nnn[term] Refer to Paragraph 4.1.3.2 for a list of event flags.

✱ESR? Standard Event Status Register Query

Input: **✱ESR?[term]**

Returned: <bit weighting>

Format: nnn[term]

Remarks: The integer returned represents the sum of the bit weighting of the event flag bits in the Standard Event Status Register. Refer to Paragraph 4.1.3.1 for a list of event flags.

✱IDN? Identification Query

Input: **✱IDN?[term]**

Returned: <manufacturer>,<model>,0,<date>[term]

Format: aaaa,aaaaaaaa,n,mmddyy

<manufacture>	Manufacturer ID
<model>	Instrument model number
0	Indicates no serial number included
<date>	Instrument firmware revision date

Example: **LSCI,MODEL460,0,020399**

Common Commands (Continued)

✱OPC Operation Complete Command

Input: **✱OPC[term]**

Remarks: Generates an Operation Complete event in the Event Status Register upon completion of all pending selected device operations. Send it as the last command in a command string.

✱OPC? Operation Complete Query

Input: **✱OPC?[term]**

Returned: 1[term]

Remarks: Places a "1" in the output queue upon completion of all pending selected device operations. Send as the last command in a command string. *Not* the same as **✱OPC**.

✱RST Reset Instrument Command

Input: **✱RST[term]**

Remarks: Sets parameters to power-up settings.

✱SRE Configure Service Request Enable Register

Input: **✱SRE <bit weighting>[term]**

Format: nnn[term]

Remarks: Each bit has a bit weighting and represents the enable/disable mask of the corresponding status flag bit in the Status Byte Register. To enable a status flag bit, send the command **✱SRE** with the sum of the bit weighting for each desired bit. Refer to Paragraph 4.1.3.1 for a list of status flags.

Example: To enable status flags 0, 2, 4, and 6, send the command **✱SRE 85[term]**. 85 is the sum of the bit weighting for each bit.

Bit	Bit Weighting	Event Name
0	1	FDR
2	4	ALM
4	16	OVI
6	64	SRQ
	85	

✱SRE? Service Request Enable Register Query

Input: **✱SRE?[term]**

Returned: <bit weighting>

Format: nnn[term] Refer to Paragraph 4.1.3.1 for a list of status flags.

✱STB? Status Byte Query

Input: **✱STB?[term]**

Returned: <bit weighting>

Format: nnn[term]

Remarks: Acts like a serial poll, but does not reset the register to all zeros. The integer returned represents the sum of the bit weighting of the status flag bits that are set in the Status Byte Register. Refer to Paragraph 4.1.3.1 for a list of status flags.

Common Commands (Continued)

✱TST?

Self-Test Query

Input: `✱TST?[term]`

Returned: <status>

Format: n

<status> 0 = no errors found, 1 = errors found

Remarks: The Model 460 reports status based on test done at power up.

✱WAI

Wait-to-Continue Command

Input: `✱WAI[term]`

Remarks: Send ✱WAI as the last command in a command string followed by appropriate termination. It cannot be embedded between other commands.

4.3.2 Interface Commands

ADDR IEEE Address Command

Input: **`ADDR <address>[term]`**

Format: nn

<address> An integer from 1 to 30. Address 0 and 31 are reserved.

Remarks: The Model 460 is factory preset to Address 12. Refer to Paragraph 3.11.

ADDR? IEEE Address Query

Input: **`ADDR?[term]`**

Returned: <address>[term]

Format: nn (Refer to command for description)

BAUD Serial Interface Baud Rate Command

Input: **`BAUD <baud>[term]`**

Format: n

<baud> 0 = 300, 1 = 1200, and 2 = 9600 baud. Refer to Paragraph 3.11.

BAUD? Serial Interface Baud Rate Query

Input: **`BAUD?[term]`**

Returned: <baud>[term]

Format: n (Refer to command for description)

BRIGT Front Panel Display Brightness Command

Input: **`BRIGT <brightness>[term]`**

Format: n

<brightness> 0 = dimmest thru 7 = brightest. Default setting is 4. Refer to Paragraph 3.12.

BRIGT? Front Panel Display Brightness Query

Input: **`BRIGT?[term]`**

Returned: <brightness>[term]

Format: n (Refer to command for description)

CODE Front Panel Keyboard Lock Code Command

Input: **`CODE <lock code>[term]`**

Format: nnn

<lock code> Enter any three numbers. Default = 123. Refer to Paragraph 3.14.

CODE? Front Panel Keyboard Lock Code Query

Input: **`CODE?[term]`**

Returned: <lock code>[term]

Format: nnn (Refer to command for description)

Interface Commands (Continued)

END
End Or Identify (EOI) Status Command

Input: `END <state>[term]`

Format: n

<state> 0 = Enabled, 1 = Disabled

Remarks: Sets the EOI status. When enabled, the hardware EOI line becomes active with the last byte of a transfer. The EOI identifies the last byte allowing for variable length data transmissions.

END?
End Or Identify (EOI) Status Query

Input: `END?[term]`

Returned: <state>[term]

Format: n (Refer to command for description)

FAST
Fast Data Mode Command

Input: `FAST <state>[term]`

Format: n

<state> 0 = Off, 1 = On

Remarks: Via the IEEE-488 Interface, Fast Data Mode reaches data rates up to18 readings per second with Vector Magnitude turned off or 14 readings per second with Vector Magnitude turned on. If using the Serial Interface, a maximum of 14 readings per second is possible at 9600 baud. With either interface, there is a corresponding increase in corrected analog output. The front panel display does not function in this mode. Refer to Paragraph 3.16.1.

FAST?
Fast Data Mode Query

Input: `FAST?[term]`

Returned: <state>[term]

Format: n (Refer to command for description)

KEY?
Front Panel Key Pressed Query

Input: `KEY?[term]`

Returned: <state>[term]

Format: n

<state> 0 = No, 1 = Yes

Remarks: Queries the gaussmeter to check for any front panel key pressed since the last query over the remote interface.

LOCK
Front Panel Keyboard Lock Command

Input: `LOCK <state>[term]`

Format: n

<state> 0 = Unlocked, 1 = Locked

Remarks: Locks out all front panel entries except pressing the **Alarm** key to silence alarms. Refer to Paragraph 3.14. Use the CODE command to set the lock code.

LOCK?
Front Panel Keyboard Lock Query

Input: `LOCK?[term]`

Returned: <state>[term]

Format: n (Refer to command for description)

Interface Commands (Continued)

MODE Local/Remote Mode Command

Input: `MODE <mode>[term]`

Format: n

<mode> 0 = Local Mode
1 = Remote Mode
2 = Remote Mode with Local Lockout

Remarks: Press the front panel **Local** key to set the Model 460 to local provided the key has not been disabled by local lockout. The Model 460 powers up in local mode. Refer to Paragraph 3.11.

Example: At the end of a command string, `MODE 0` maintains constant local operation.

MODE? Local/Remote Mode Query

Input: `MODE?[term]`

Returned: <mode>[term]

Format: n (Refer to command for description)

SLEEP Current Source Command

Input: `SLEEP <state>[term]`

Format: n

<state> 0 = On, 1 = Off

Remarks: Turns off all current sources. Useful to gather a sensitive measurement elsewhere in a system where gaussmeter current sources may interfere with measurement. Refer to Paragraph 3.16.2.

SLEEP? Current Source Query

Input: `SLEEP?[term]`

Returned: <state>[term]

Format: n (Refer to command for description)

TERM Terminator Command

Input: `TERM <terminator>[term]`

Format: n

<terminator> 0 = Carriage return and line feed (CR)(LF^{EOI})
1 = Line feed and carriage return (LF)(CR^{EOI})
2 = Line feed (LF^{EOI})
3 = No terminating characters – EOI line set with last data byte if enabled (End)

Remarks: Sets the terminating character type. Terminating characters are sent when the Model 460 completes its message transfer on output. They also identify the end of an input message. This command works only with the IEEE-488 Interface and does not change the serial terminators. Refer to Paragraph 3.11.

TERM? Terminator Query

Input: `TERM?[term]`

Returned: <terminator>[term]

Format: n (Refer to command for description)

4.3.3 Device Specific Commands

ACDC AC/DC Magnetic Field Reading Command

Input: **`ACDC <mode>[term]`**

Format: n

<mode> 0 = DC, 1 = AC

Remarks: Configures the unit for AC or DC measurements. The AC field is further defined by the PRMS (Peak or RMS) command. Refer to Paragraph 3.5.

ACDC? AC/DC Magnetic Field Reading Query

Input: **`ACDC?[term]`**

Returned: <mode>[term]

Format: n (Refer to command for description)

ALARM Alarm Function On/Off Command

Input: **`ALARM <state>[term]`**

Format: n

<state> 0 = Off, 1 = On. Refer to Paragraph 3.10.

ALARM? Alarm Query

Input: **`ALARM?[term]`**

Returned: <state>[term]

Format: n (Refer to command for description)

ALLF? All Fields Query

Input: **`ALLF?[term]`**

Returned: <field value>[term]

Format: ±nnn.nn

<field value> Returns sign, 4 or 5 digits, and places decimal point appropriate to range.

Remarks: Returns the X axis reading, the Y axis, the Z axis, then the Vector Magnitude.

ALMB Audible Alarm Command

Input: **`ALMB <state>[term]`**

Format: n

<state> 0 = Disabled, 1 = Enabled

ALMB? Audible Alarm Query

Input: **`ALMB?[term]`**

Returned: <state>[term]

Format: n (Refer to command for description)

Device Specific Commands (Continued)

ALMH Alarm High Point Command

Input: `ALMH <field value>[term]`

Format: ±nnn.nn

<field value> Returns sign, 4 or 5 digits, and places decimal point appropriate to range.

Remarks: New value is entered on the same field range as the old value. Setting value to zero first will change the setting range to present display range.

ALMH? Alarm High Point Query

Input: `ALMH?[term]`

Returned: <field value>[term]

Format: ±nnn.nn (Refer to command for description)

Remarks: Use ALMHM? to determine units multiplier.

ALMHM? Alarm High Point Multiplier Query

Input: `ALMHM?[term]`

Returned: <multiplier>[term]

Format: a

<multiplier> u = micro = 10^{-6}, m = milli = 10^{-3}, (blank) = unity, k = kilo = 10^{3}

Remarks: Used with ALMH? query.

ALMIO Alarm Inside/Outside Command

Input: `ALMIO <inout>[term]`

Format: n

<inout> 0 = Outside or 1 = Inside

Remarks: Instructs alarm feature to cause an active alarm state when the field reading is either inside of or outside of the high and low setpoint values. Refer to Paragraph 3.10.

ALMIO? Alarm Inside/Outside Query

Input: `ALMIO?[term]`

Returned: <inout>[term]

Format: n (Refer to command for description)

ALML Alarm Low Point Command

Input: `ALML <field value>[term]`

Format: ±nnn.nn

<field value> Returns sign, 4 or 5 digits, and places decimal point appropriate to range.

Remarks: New value is entered on the same field range as the old value. Setting value to zero first will change the setting range to present display range.

Device Specific Commands (Continued)

ALML? Alarm Low Point Query

Input: `ALML?[term]`
Returned: <field value>[term]
Format: ±nnn.nn (Refer to command for description)
Remarks: Use ALMLM? to determine units multiplier.

ALMLM? Alarm Low Point Multiplier Query

Input: `ALMLM?[term]`
Returned: <multiplier>[term]
Format: a
<multiplier> u = micro = 10^{-6}, m = milli = 10^{-3}, (blank) = unity, k = kilo = 10^{3}
Remarks: Used with ALML? query.

ALMS? Alarm Status Query

Input: `ALMS?[term]`
Returned: <state>[term]
Format: n
<state> 0 = Off, 1 = On
Remarks: Queries current alarm status. Off means no alarm condition exists, On means an alarm exists.

ANOD Default Corrected Analog Out Command

Input: `ANOD <mode>[term]`
Format: n
<mode> 0 = Off (user selected scale)
1 = On (default scale)
2 = Analog output controlled by remote interface (refer to **AOCON**).
Remarks: Sets default analog output status.

ANOD? Default Corrected Analog Out Query

Input: `ANOD?[term]`
Returned: <mode>[term]
Format: n (Refer to command for description)

ANOH Analog Out High Setpoint Command

Input: `ANOH <field value>[term]`
Format: ±nnn.nn
<field value> Enter sign, 4 or 5 digits, and place decimal point appropriate to range.
Remarks: New value is entered on the same field range as the old value. Setting value to zero first will change the setting range to present display range.

Device Specific Commands (Continued)

ANOH? Analog Out High Setpoint Query

Input: **`ANOH?[term]`**
Returned: <field value>[term]
Format: ±nnn.nn (Refer to command for description)
Remarks: Use ANOHM? to determine units multiplier.

ANOHM? Analog Out High Setpoint Multiplier Query

Input: **`ANOHM?[term]`**
Returned: <multiplier>[term]
Format: a
<multiplier> u = micro = 10^{-6}, m = milli = 10^{-3}, (blank) = unity, k = kilo = 10^{3}
Remarks: Used with ANOH? query.

ANOL Analog Out Low Setpoint Command

Input: **`ANOL <field value>[term]`**
Format: ±nnn.nn
<field value> Enter sign, 4 or 5 digits, and place decimal point appropriate to range.
Remarks: New value is entered on the same field range as the old value. Setting value to zero first will change the setting range to present display range.

ANOL? Analog Out Low Setpoint Query

Input: **`ANOL?[term]`**
Returned: <field value>[term]
Format: ±nnn.nn (Refer to command for description)
Remarks: Use ANOLM? to determine units multiplier.

ANOLM? Analog Out Low Setpoint Multiplier Query

Input: **`ANOLM?[term]`**
Returned: <multiplier>[term]
Format: a
<multiplier> u = micro = 10^{-6}, m = milli = 10^{-3}, (blank) = unity, k = kilo = 10^{3}
Remarks: Used with ANOL? query.

ANOS Corrected Analog Output Source Command

Input: **`ANOS <source>[term]`**
Format: n
<source> 1 = X
2 = Y
3 = Z
4 = V
Remarks: Defines the corrected analog output source channel. Refer to Paragraph 3.13.1.

Device Specific Commands (Continued)

ANOS? Corrected Analog Output Source Query

Input: **`ANOS?[term]`**

Returned: <source>[term]

Format: n (Refer to command for description)

AOCON Analog Output Control Mode Command

Input: **`AOCON <percent>[term]`**

Format: ±nnn.nn

<percent> Sets bipolar output voltage in percent of full scale. Allows resolution of 0.01%.

Remarks: As a safety precaution, this setting always equals zero if the instrument loses power or is turned off. The setting cannot be changed from the front panel. Refer to Paragraph 3.13.3.

Example: The command **`AOCON -50.25`** sets output to –50.25% of full scale. This is –5.025 volts for a ±10 volt output or –1.5075 volts for a ±3 volt output.

AOCON? Analog Output Control Mode Query

Input: **`AOCON?[term]`**

Returned: <percent>[term]

Format: ±nnn.nn (Refer to command for description)

AUTO Auto Range Command

Input: **`AUTO <state>[term]`**

Format: n

<state> 0 = Auto Range Off, 1 = Auto Range On. Refer to Paragraph 3.4.

AUTO? Auto Range Query

Input: **`AUTO?[term]`**

Returned: <state>[term]

Format: n (Refer to command for description)

CHNL Channel Command

Input: **`CHNL <channel>[term]`**

Format: a

<channel> X = Channel X
Y = Channel Y
Z = Channel Z
V = Vector Magnitude Channel

Remarks: Directs commands to the specified channel. Subsequent commands apply to the specified channel until a new CHNL command is sent or the unit is powered off and back on again. Refer to Paragraph 3.1.4.

CHNL? Channel Query

Input: **`CHNL?[term]`**

Returned: <channel>[term]

Format: a (Refer to command for description)

Device Specific Commands (Continued)

FIELD? Magnetic Field Reading Query

Input: `FIELD?[term]`

Returned: <field value>[term]

Format: ±nnn.nn
<field value> Returns sign, 4 or 5 digits, and places decimal point appropriate to range.

Remarks: Use FIELDM? to determine units multiplier and UNITS? to determine gauss or tesla units.

FIELDM? Magnetic Field Reading Multiplier Query

Input: `FIELDM?[term]`

Returned: <multiplier>[term]

Format: a
<multiplier> u = micro = 10^{-6}, m = milli = 10^{-3}, (blank) = unity, k = kilo = 10^{3}

Remarks: Used with FIELD? query.

FILT Display Filter Command

Input: `FILT <state>[term]`

Format: n
<state> 0 = Off, 1 = On

Remarks: Quiets the display reading by a degree depending on the points (FNUM) and window (FWIN) settings. Refer to Paragraph 3.6.

FILT? Display Filter Query

Input: `FILT?[term]`

Returned: <state>[term]

Format: n (Refer to command for description)

FNUM Display Filter Points Command

Input: `FNUM <points>[term]`

Format: nn
<points> Integer from 2 thru 64

Remarks: Sets filter points. Numbers 2 thru 8 produce a linear filter response. Numbers 9 thru 64 produce an exponential filter response. In general, the higher the number, the longer the display settle time. Refer to Paragraph 3.6.

FNUM? Display Filter Points Query

Input: `FNUM?[term]`

Returned: <points>[term]

Format: nn (Refer to command for description)

Device Specific Commands (Continued)

FWIN Display Filter Window Command

Input: `FWIN <window>[term]`

Format: nn

<points> Integer from 1 thru 10

Remarks: Sets the filter window from 1% thru 10%. The smaller the percentage, the smaller the change in magnetic field that causes the filter to restart. Refer to Paragraph 3.6.

FWIN? Display Filter Window Query

Input: `FWIN?[term]`

Returned: <window>[term]

Format: nn (Refer to command for description)

MAX Max Hold Command

Input: `MAX <state>[term]`

Format: n

<state> 0 = Off, 1 = On

Remarks: Works with the MAXR and MAXC commands. Refer to Paragraph 3.2.

MAX? Max Hold Query

Input: `MAX?[term]`

Returned: <state>[term]

Format: n (Refer to command for description)

MAXC Max Clear (Reset) Command

Input: `MAXC[term]`

Remarks: This command initiates a Max Reset. Upon entry, the Max Hold function is zeroed out and a new peak is captured. Refer to Paragraph 3.2.

MAXR? Max Reading Query

Input: `MAXR?[term]`

Returned: <field value>[term]

Format: +nnn.nn

<field value> Returns plus (+) sign, 4 or 5 digits, and decimal point appropriate to range.

Remarks: Use MAXRM? to determine units multiplier and UNITS? to determine gauss or tesla units.

Device Specific Commands (Continued)

MAXRM? Max Reading Multiplier Query

Input: **`MAXRM?[term]`**

Returned: <multiplier>[term]

Format: a

<multiplier> u = micro = 10^{-6}, m = milli = 10^{-3}, (blank) = unity, k = kilo = 10^{3}

Remarks: Used with MAXR? query.

PRMS Peak/RMS Field Reading Command

Input: **`PRMS <state>[term]`**

Format: n

<state> 0 = RMS, 1 = Peak

Remarks: Configures unit for RMS or Peak measurements. RMS or Peak is selected after ACDC is set to AC. Refer to Paragraph 3.5.

PRMS? Peak/RMS Field Reading Query

Input: **`PRMS?[term]`**

Returned: <state>[term]

Format: n (Refer to command for description)

RANGE Manual Range Command

Input: **`RANGE <range>[term]`**

Format: n

<range> 0 = first range (highest)
1 = second range
2 = third range,
3 = fourth range (lowest)

Remarks: Range depends on type of probe installed. There are four ranges possible for each probe. Refer to Paragraph 3.4.

RANGE? Manual Range Query

Input: **`RANGE?[term]`**

Returned: <range>[term]

Format: n (Refer to command for description)

REL Relative Mode Command

Input: **`REL <state>[term]`**

Format: n

<state> 0 = Off, 1 = On

Remarks: Works with the RELR(?), RELRM(?), RELS(?), and RELSM(?) commands. Remote operation is slightly different from front panel operation described in Paragraph 3.9. From the front panel, the current reading is captured as the setpoint when Relative is turned on. However, when activated by remote command, the initial relative setpoint is zero. The RELS command is used to enter a setpoint.

Device Specific Commands (Continued)

REL?

Relative Mode Query

Input: `REL?[term]`

Returned: <state>[term]

Format: n (Refer to command for description)

RELR?

Relative Mode Reading Query

Input: `RELR?[term]`

Returned: <field value>[term]

Format: ±nnn.nn

<field value> Returns sign, 4 or 5 digits, and places decimal point appropriate to range.

Remarks: Use RELRM? to determine units multiplier and UNITS? to determine gauss or tesla units.

RELRM?

Relative Mode Reading Multiplier Query

Input: `RELRM?`

Returned: <multiplier>[term]

Format: a

<multiplier> u = micro = 10^{-6}, m = milli = 10^{-3}, (blank) = unity, k = kilo = 10^{3}

Remarks: Used with RELR? query.

RELS

Relative Mode Setpoint Command

Input: `RELS <field value>[term]`

Format: ±nnn.nn

<field value> Relative mode setpoint value with up to 5 digits resolution.

Remarks: New value is entered on the same field range as the old value. Setting value to zero first will change the setting range to present display range.

RELS?

Relative Mode Setpoint Query

Input: `RELS?[term]`

Returned: <field value>[term]

Format: ±nnn.nn (Refer to command for description)

Remarks: Use RELSM? to determine units multiplier.

RELSM?

Relative Mode Setpoint Multiplier Query

Input: `RELSM?[term]`

Returned: <multiplier>[term]

Format: a

<multiplier> u = micro = 10^{-6}, m = milli = 10^{-3}, (blank) = unity, k = kilo = 10^{3}

Remarks: Used with RELS? query.

Device Specific Commands (Continued)

UNIT Gauss/Tesla Units Command

Input: `UNIT <unit>[term]`

Format: a

<unit> G = gauss, T = tesla. Refer to Paragraph 3.8.

UNIT? Gauss/Tesla Unit Query

Input: `UNIT?[term]`

Returned: <unit>[term]

Format: a (Refer to command for description)

VSRC Vector Magnitude Source Command

Input: `VSRC <source>[term]`

Format: n

<source> 1 = XYZ, 2 = XY, 3 = XZ, 4 = YZ, 5 = X – Y

Remarks: Sets the source of Vector Magnitude channel calculations. Refer to Paragraph 3.1.5.

VSRC? Vector Magnitude Source Query

Input: `VSRC?[term]`

Returned: <source>[term]

Format: n (Refer to command for description)

4.3.4 Probe Specific Commands

FCOMP Field Compensation Command

Input: `FCOMP <state>[term]`

Format: n

<state> 0 = Off, 1 = On

Remarks: Turns set field compensation On or Off. If Off, probe field compensation table, if present, is ignored. Refer to Paragraph 3.7.

FCOMP? Field Compensation Query

Input: `FCOMP?[term]`

Returned: <state>[term]

Format: n (Refer to command for description)

ONOFF Probe On/Off Command

Input: `ONOFF <state>[term]`

Format: n

<state> 0 = Off, 1 = On

Remarks: Sets probe on/off status. First specify channel X, Y, or Z with the CHNL command.

Probe Specific Commands (Continued)

ONOFF? Probe On/Off Query

Input: `ONOFF?[term]`

Returned: <state>[term]

Format: n (Refer to command for description)

SNUM? Probe Serial Number Query

Input: `SNUM?[term]`

Returned: <serial>[term]

Format: annnnnnnnn

<serial> The current probe serial number format is Hnnnnn, though there is room for up to a ten-character response.

TCOMP Temperature Compensation Command

Input: `TCOMP <state>[term]`

Format: n

<state> 0 = Off, 1 = On

Remarks: Turns set temperature compensation On or Off. If off, probe temperature compensation, if present, is ignored. Refer to Paragraph 3.7.

TCOMP? Temperature Compensation Query

Input: `TCOMP?[term]`

Returned: <state>[term]

Format: n (Refer to command for description)

TYPE? Probe Type Query

Input: `TYPE?[term]`

Returned: <type>[term]

Format: n

<type> 0 = High Sensitivity (HSE)
1 = High Stability (HST)
2 = Ultra-High Sensitivity (UHS)

Remarks: Refer to Paragraph 5.2.

ZCAL Zero Probe Command

Input: `ZCAL[term]`

Remarks: This command initiates the Zero Probe function. Place probe in the Zero Gauss Chamber first and then enter the ZCAL command. Refer to Paragraph 3.3.

CHAPTER 5
ACCESSORIES AND PROBES

5.0 GENERAL

This chapter provides information on the accessories and probes available for the Model 460 Gaussmeter. Model numbers are detailed in Paragraph 5.1; accessories in Paragraph 5.2, Lake Shore standard probes in Paragraph 5.3, Helmholtz coils in Paragraph 5.4, and reference magnets in Paragraph 5.5.

5.1 MODELS

The list of Model 460 Model numbers is provided as follows.

Model	*Description*
460	**Standard Model 460 3-Channel Gaussmeter.** Features ±3 volt corrected analog output.
460-10	**Optional Model 460 3-Channel Gaussmeter.** Features ±10 volt corrected analog output.

5.2 ACCESSORIES

Accessories are devices that perform a secondary duty as an aid or refinement to the primary unit.

Model	*Description*
109-053 *	**Clamp-On Ferrite Filter**. Electromagnetic Compatibility (EMC) noise suppression device.
115-006 *	**Detachable 120 VAC Line Cord.**
4001	**RJ-11 Cable Assembly**. Four-Wire Cable Assembly with RJ-11 plugs on each end. Used with RS-232C Interface. Cable is 4 meters (14 feet) long. See Figure 5-17.
4002	**RJ-11 to DB-25 Adapter**. Adapts RJ-11 receptacle to female DB-25 connector. Connects Model 460 to RS-232C Serial Port on rear of Customer's computer. See Figure 5-18.
4003	**RJ-11 to DE-9 Adapter**. Adapts RJ-11 receptacle to female DE-9 connector. Connects Model 460 to RS-232C Serial Port on rear of Customer's computer. See Figure 5-19.
4004	**IEEE-488 Interface Cable.** Connects Model 460 to customer-supplied computer with IEEE-488 Interface. Cable is 1 meter (3 feet) long.
RM-1	**Rack Mounting Kit.** Mounting ears and hardware to attach one Model 460 to a 483 mm (19-inch) rack mount space.
4030-XX	**Hall Probe Stand**. This moveable probe stand consists of a 30 mm square post mounted on a 180 x 130 x 22.5 mm thick base plate. A probe holder is integrated into the stand. The holder can be moved up or down and fixed at any angle and location along the post. Two models are available as follows. Consult factory for other post heights. **4030-12** Hall probe stand with 12 inch tall post and probe holder to accept 3/8 inch diameter Hall probe handle. **4030-24** Hall probe stand with 24 inch tall post and probe holder to accept 3/8 inch diameter Hall probe handle.
4060 *	**Standard Zero Gauss Chamber.** Calibrates standard probes. Size: 32 × 32 × 61 mm (1.3 × 1.3 × 2.4 in.). Bore: 12 mm dia. × 51 mm deep (0.5 × 2 in.). See Figure 5-15.
4065	**Large Zero Gauss Chamber.** Calibrates Gamma Probe™. Size: 57 × 53 × 305 mm (2.25 × 2.1 × 12 in.). Bore: 19 mm dia. × 279 mm deep (0.75 × 11 in.). See Figure 5-16.
MAN-460 *	**Model 460 Gaussmeter User's Manual**.

* Included with purchase of gaussmeter.

Accessories (Continued)

Model	*Description*
MCBL-XX	**Hall Generator Cable Assembly**. The MCBL Cable Assembly connects a discrete Hall generator to the Model 460 Gaussmeter. The cable ships with the HALLCAL.EXE program which permits cable PROM programming through a PC (or compatible) computer serial port. Because of the many calibration intricacies, the user is responsible for measurement accuracy. Refer to Appendix C. **MCBL-6** Hall Generator Cable Assembly – 2 meters (6 feet) long **MCBL-20** Hall Generator Cable Assembly – 6 meters (20 feet) long
MH-XX	**Helmholtz Coils**. Provides stable low magnetic field when used with customer-supplied power supply. Often used to provide reference field to help check gaussmeter accuracy. Three coils are available as follows. Refer to Paragraph 5.3. **MH-2.5** Helmholtz Coil, 2.5-inch inner diameter, field strength: ≈30 G @ 1 A, maximum continuous current: 2 A, coil resistance: ≈3 Ω. See Figure 5-11. **MH-6** Helmholtz Coil, 6-inch inner diameter, field strength: ≈25 G @ 1 A, maximum continuous current: 2 A, Coil Resistance: ≈10 Ω. See Figure 5-12. **MH-12** Helmholtz Coil. 12-inch inner diameter, field strength: ≈12 G @ 1 A, maximum continuous current: 2 A, Coil Resistance: ≈20 Ω. See Figure 5-13.
MRA-XXX **MRT-XXX**	**Reference Magnets**. High-quality reference magnets are available in transverse (flat) and axial (round) configurations. Refer to Paragraph 5.4 and see Figure 5-14. **MRA-312-100** Axial Reference Magnet: 0.312" inside diameter, 100 G, 1% **MRA-312-200** Axial Reference Magnet: 0.312" inside diameter, 200 G, 1% **MRA-312-300** Axial Reference Magnet: 0.312" inside diameter, 300 G, 1% **MRA-312-500** Axial Reference Magnet: 0.312" inside diameter, 500 G, 1% **MRA-312-1K** Axial Reference Magnet: 0.312" inside diameter, 1 kG, 1% **MRA-312-2K** Axial Reference Magnet: 0.312" inside diameter, 2 kG, 1% **MRT-062-200** Transverse Reference Magnet: 0.062" gap, 200 G, 1% **MRT-062-500** Transverse Reference Magnet: 0.062" gap, 500 G, 1% **MRT-062-1K** Transverse Reference Magnet: 0.062" gap, 1 kG, 0.5% **MRT-062-2K** Transverse Reference Magnet: 0.062" gap, 2 kG, 0.5% **MRT-062-5K** Transverse Reference Magnet: 0.062" gap, 5 kG, 0.5% **MRT-062-10K** Transverse Reference Magnet: 0.062" gap, 10 kG, 5% **MRT-343-50** Transverse Reference Magnet: 0.343" gap, 50 G, 1% **MRT-343-100** Transverse Reference Magnet: 0.343" gap, 100 G, 1%
MPEC-XXX	**Probe Extension Cables**. Four cables are available. Each extension cable contains a EEPROM for calibration data. Each extension cable must be matched to a specific probe. To maintain probe accuracy, that probe and extension cable must be calibrated together at Lake Shore. The probe will exhibit its full accuracy if used without the extension cable. Part numbers and cables lengths are defined as follows: **MPEC-10** Probe Extension Cable – 3 meters (10 feet) **MPEC-25** Probe Extension Cable – 7.6 meters (25 feet) **MPEC-50** Probe Extension Cable – 15.2 meters (50 feet) **MPEC-100** Probe Extension Cable – 30.5 meters (100 feet)

5.3 LAKE SHORE STANDARD PROBES

There are several types of Lake Shore Model 460 probes available: 2- and 3-Axis, Axial, Gamma, Tangential, and Transverse—each named for its Hall sensor orientation. Because the Model 460 covers such a wide magnetic field range (0.01 mG to 300 kG), three probe ranges are available: High Stability (HST), High Sensitivity (HSE), and Ultra-High Sensitivity (UHS). Please consult the factory for availability of probe types not detailed in this section. Information on Hall generators is presented in Appendix C of this manual.

5.3.1 Probe Selection Criteria

Some guidelines are provided below to aid in the selection of a probe for you application.

1. Choose a probe to match the application. Do not buy more accuracy, field range, or fragility than is actually necessary.
2. The thinner a probe, the more fragile it is. Try to avoid the temptation to select an easily damaged probe based on a possible, but not probable, future application. For instance, avoid using an exposed-device probe such as a Model MFT-3E03 or MNA-1904 type for general field measurements. *Once a stem or sensor has been damaged, the probe is not repairable.*
3. Metal enclosed probes, such as the Model MMT-6J08 and MMA-2508 types, offer the greatest amount of protection to the Hall sensor, and therefore are the most rugged types.
4. Be cautious about using aluminum stemmed, transverse probes, such as the Model MMT-6J08 type, where AC magnetic fields are to be measured. Eddy currents in the stem material can affect reading accuracy. A superior choice for AC measurements would b the Model MNT-4E04 type fiberglass-epoxy stem probes.
5. Several stem lengths are offered for each probe type. User preferences or test set-up dimensions usually determine the final selection. Longer stems are more susceptible to accidental bending (in many cases not catastrophic, but bothersome). Stem length does not affect performance.
6. Be aware of the differences in the probe "active areas" shown on the data sheet. A Hall effect probe will indicate the average field value sensed over that total active area. Thus, when measuring magnetic fields with a high gradient across the sensor width, choose the smallest active area practical (keeping in mind, however, the fragility rule in number 2 above).
7. Lake Shore gaussmeter probes exhibit different ranges of magnetic fields over which they will provide valid readings. Check the specification sheet for these usable ranges. High Stability probes, such as those whose model numbers end in -VG, are usable on full scale ranges of 300 gauss (30 millitesla) to 30 kilogauss (3 tesla). The High Sensitivity family of probes (i.e., -VH models) can be used on 30 G (3 mT) to 30 kG (3 T) full scale ranges. High field probes are specially calibrated to provide use above 30 kG (3 T), and the Gamma Probe operates on the 300 mG (30 µT) and 3 G (300 µT) ranges.
8. If none of the standard probe configurations seem to fit your needs, always remember that Lake Shore can provide custom probes to meet your physical, temperature, and accuracy requirements. Contact Lake Shore with details of your special requirements.

5.3.2 Radiation Effects on Gaussmeter Probes

The HST and HSE probes use a highly doped indium arsenide active material. The HST material is the more highly doped of the two and therefore will be less affected by radiation. Some general information relating to highly doped indium arsenide Hall generators is as follows:

- Gamma radiation seems to have little effect on the Hall generators.
- Proton radiation up to 10 Mrad causes sensitivity changes <0.5%.
- Neutron cumulative radiation (>0.1 MeV, 10^{15}/sq. cm.) can cause a 3 to 5% decrease in sensitivity.
- In all cases the radiation effects seem to saturate and diminish with length of time exposed.

5.3.3 2-Axis and 3-Axis Probes

At the tip of Lake Shore 2-Axis probes are one transverse and one axial Hall sensor. 3-Axis probes contain two transverse and one axial Hall sensor. These sensors are recessed in the non-metallic Phenolic mounting block—Phenolic permits AC and DC measurements—whereas aluminum limits probes to DC measurements.

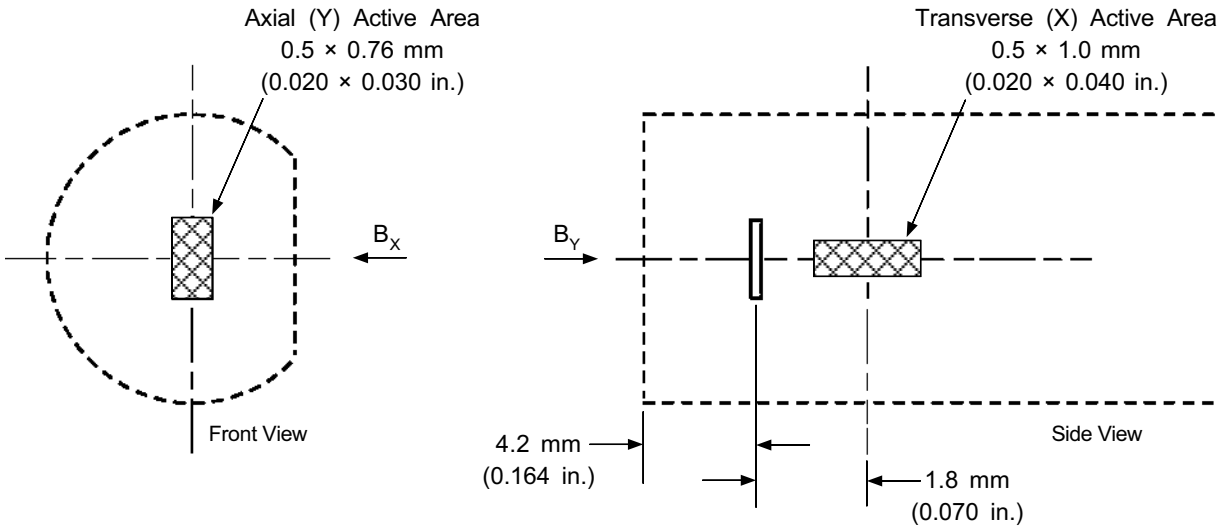
The active area for each sensor is defined as the portion of the Hall plate where the majority of magnetic sensitivity occurs. See Figures 5-1 and 5-2 and refer to the following table.

Probe Type	*Active Area*	*Distance From Tip of Probe*
2-Axis: Axial (B_Y) Sensor	0.5 × 1.0 mm (0.020 × 0.040 in.)	4.2 mm (0.164 in.)
2-Axis: Transverse (B_X) Sensor	0.5 × 1.0 mm (0.020 × 0.040 in.)	5.9 mm (0.234 in.)
3-Axis (for all 3 axes)	0.5 × 1.0 mm (0.020 × 0.040 in.)	1.8 mm (0.070 in.)

The probe tip is very fragile; protect it from any abrasions, blows, bends, stress, or excessive temperatures. Take care during measurements to place no pressure on the probe tip. *Hold the probe in place only by securing the handle.* Never apply force to the probe stem. Any strain on the Phenolic may alter the probe calibration, and excessive force may destroy the Hall sensors.

Both 2 & 3-axis probes provide more consistent readings in a low gradient magnetic field. The higher the gradient, the higher the error caused by the Hall sensors not occupying the same point in space.

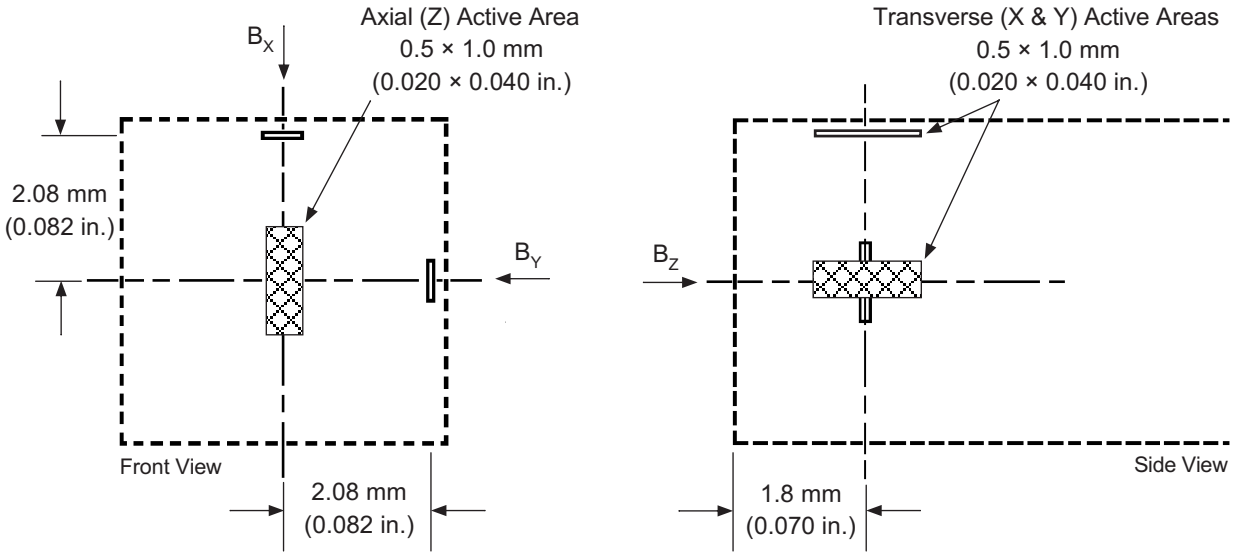
Connect the probes to their respective connectors on the Model 460 rear panel. Note that neither the Y nor Z probe functions if the X channel is turned off or disconnected. Each connector is marked with the channel (axis) designation. A single channel probe may be connected to the Z channel while a 2-axis probe uses the X and Y channels.



NOTE: Active area is defined as the portion of the Hall plate where the majority of magnetic sensitivity occurs. All position dimensions of the active area adhere to a tolerance of ±0.25 mm (0.010 in.). Each active area is perpendicular to the other two to within ±0.5°.

C-460-5-1.eps

Figure 5-1. 2-Axis Probe Tip Details



NOTE: Active area is defined as the portion of the Hall plate where the majority of magnetic sensitivity occurs. All position dimensions of the active area adhere to a tolerance of ±0.25 mm (0.010 in.). Each active area is perpendicular to the other two to within ±0.5°.

C-460-5-2.eps

Figure 5-2. 3-Axis Probe Tip Details

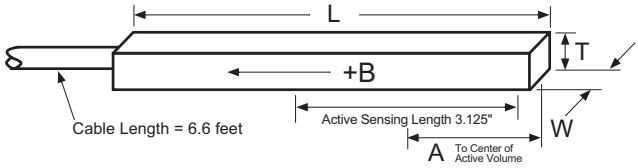
5.3.4 Probe Specifications

Terminology used in Figures 5-3 thru 5-10 are defined as follows:

Definition of Probe Terminology
A = Distance from tip to center line of active area +B = Magnetic flux density vector (for + reading) HST = High Stability Probe HSE = High Sensitivity Probe UHS = Ultra-High Sensitivity Probe

	Usable Full-Scale Ranges Vs. Probe Type			
Type	**HST-1**	**HST-2**	**HSE-1**	**UHS-1**
Usable on Ranges	300 G	300 G	30 G	300 mG
	3 kG	3 kG	300 G	3 G
	30 kG	30 kG	3 kG	30 G
	300 kG	—	30 kG	—

GAMMA PROBE



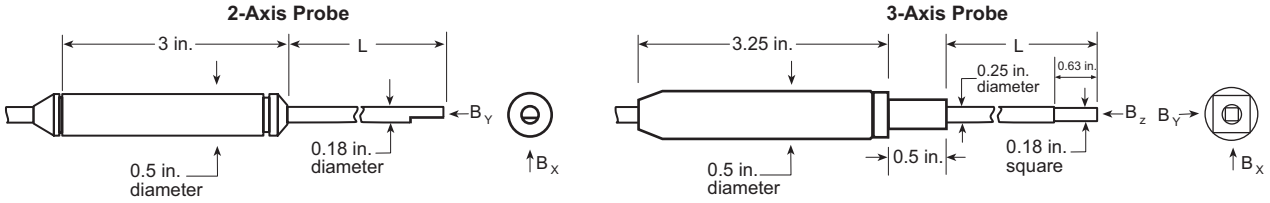
Small variations in, or low values of large volume magnetic fields, such as that of the Earth or fringe fields, around large solenoids, can be measured with these ultra-high sensitivity probes. Resolutions of several gammas (10^{-5} G) to tens of gammas are available depending on the mating gaussmeter. Application is optimum when fields are homogeneous over lengths greater than 1 foot. The active sensing length of the gamma probe is 3.125 inches.

Model No.	W	T	A	L	Frequency Range	Type	Corrected Accuracy (% of Reading)	Operating Temperature Range	Temperature Coefficient (Maximum)	
									Zero	Calibration
MLA-5006-HJ	0.25 ±0.03"	0.5"	2.2"	5.7"	DC, 10 to 400 Hz	UHS-1	±0.5% to 2 gauss	0 °C to +75 °C	1 mG/°C	±0.02%/°C

Gamma.eps

Figure 5-3. Definition of Lake Shore Gamma Probe

2- & 3-AXIS PROBES



2-Axis Probe

Model No.	L	Stem Material	Frequency Range	Type	Corrected Accuracy (% of RDG)	Operating Temperature Range	Temperature Coefficient	
							Zero	Calibration
MMY-1802-UH	2 ±0.125"	Aluminum	DC and 10 Hz to 400 Hz	HSE-1	0.25% to 20 kG 0.5% from 20 to 30 kG	10 °C to 40 °C	±0.09 gauss/°C	±0.015%/ °C
MMY-1808-UH	8 ±0.125"							
MMY-1818-UH	18 ±0.25"							
MMY-1836-UH	36 ±0.25"							

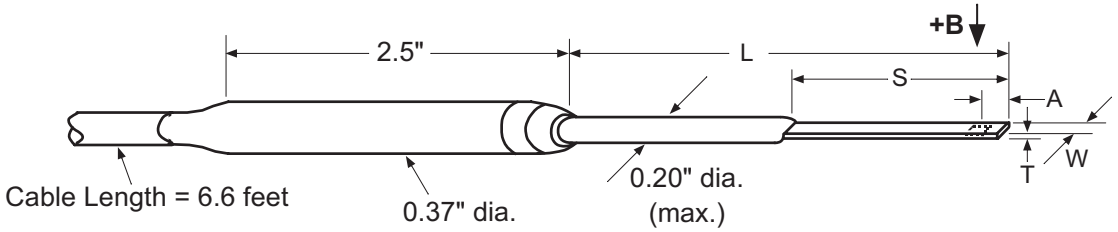
3-Axis Probe

MMZ-2502-UH	2.125 ±0.125"	Alum-inum	DC and 10 Hz to 400 Hz	HSE-1	0.25% to 20 kG 0.5% from 20 to 30 kG	10 °C to 40 °C	±0.09 gauss/°C	±0.015%/ °C
MMZ-2508-UH	8.125 ±0.125"							
MMZ-2512-UH	12.125 ±0.125"							
MMZ-2518-UH	18.125 ±0.25"							
MMZ-2536-UH	36.125 ±0.25"							
MMZ-2560-UH	60.375 ±0.5"							

2-3_Axis.eps

Figure 5-4. Definition of Lake Shore 2- and 3-Axis Probes

ROBUST (BRASS STEM) TRANSVERSE PROBES

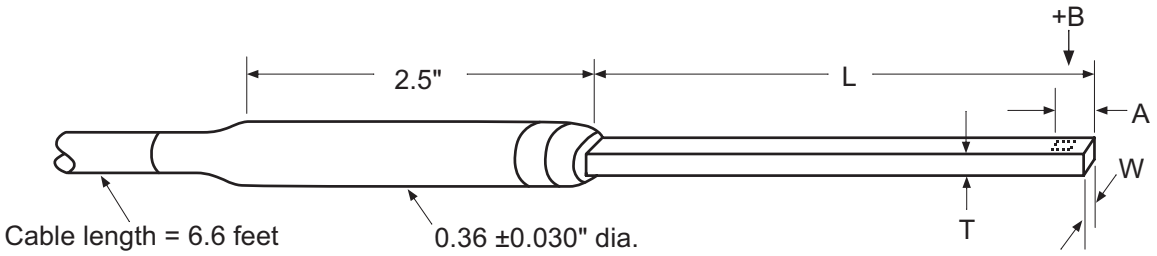


Model No.	L	S	W	T	A	Active Area	Stem Material	Frequency Range	Type	Corrected Accuracy (% of Reading)	Operating Temperature Range	Temperature Coefficient (maximum)	
												Zero	Calibration
MMTB-6J02-VH	2 ±0.125"	1.75"	0.22"	0.061" max	0.150"	0.040" dia. approx.	Brass	DC	HSE-1	±0.25% to 30 kG	0 °C to 75 °C	±0.09 G/°C	±0.015%/°C
MMTB-6J04-VH	4 ±0.125"	3.5" to 4"											
MMTB-6J08-VH	8 ±0.125"												
MMTB-6J02-VG	2 ±0.125"	1.75"							HST-2	±0.15% to 30 kG		±0.13 G/°C	–0.005%/°C
MMTB-6J04-VG	4 ±0.125"	3.5" to 4"											
MMTB-6J08-VG	8 ±0.125"												

Brass_Transverse.eps

Figure 5-5. Definition of Lake Shore Robust (Brass Stem) Transverse Probes

TRANSVERSE PROBES

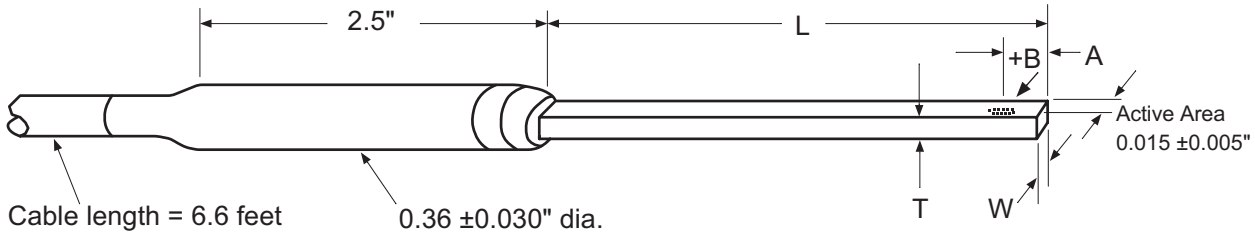


Model No.	L	T	W	A	Active Area	Stem Material	Freq. Range	Type	Corrected Accuracy (% of rdg)	Op. Temp. Range	Temperature Coefficient (Max.)	
											Zero	Calibration
MMT-6J02-VH	2 ±0.125"	0.061" max.	0.180 ±0.005"	0.150 ± 0.050"	0.040" dia. approx.	Alum.	DC	HSE-1	±0.25% to 30 kG	0 °C to +75 °C	±0.09 Gauss per °C	±0.015% per °C
MMT-6J04-VH	4 ±0.125"											
MMT-6J08-VH	8 ±0.125"											
MMT-6J18-VH	18 ±0.25"											
MNT-4E02-VH	2 ±0.125"	0.045" max.	0.150 ±0.005"			Rigid Glass Epoxy	DC, 10 to 400 Hz					
MNT-4E04-VH	4 ±0.125"											
MMT-6J02-VG	2 ±0.125"	0.061" max.	0.180 ±0.005"			Alum.	DC	HST-2	±0.15% to 30 kG		±0.13 Gauss per °C	–0.005% per °C
MMT-6J04-VG	4 ±0.125"											
MMT-6J08-VG	8 ±0.125"											
MMT-6J18-VG	18 ±0.125"											
MNT-4E02-VG	2 ±0.125"	0.045" max.	0.150 ±0.005"			Rigid Glass Epoxy	DC, 10 to 400 Hz					
MNT-4E04-VG	4 ±0.125"											
MCT-3160-WN	61 ±1"	0.25 dia. ±0.010"		0.210 ±0.050"		Stainless Steel		HST-1	±2% to 100 kG	1.5 K to 350 K		±0.010% per °C

Transverse.eps

Figure 5-6. Definition of Lake Shore Transverse Probes

TANGENTIAL PROBE

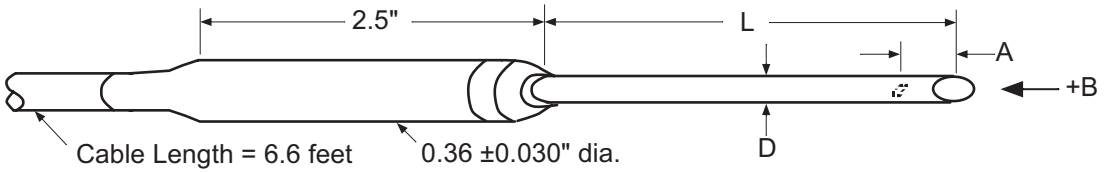


Model No.	L	T	W	A	Active Area	Stem Material	Freq. Range	Type	Corrected Accuracy (% of rdg)	Op. Temp. Range	Temperature Coefficient (Max.)	
											Zero	Calibration
MNTAN-DQ02-TH	1.5" ±0.125"	0.125" max.	0.38" max.	0.030" ±0.005"	0.020" dia. approx.	Plastic	DC, 10 to 400 Hz	HSE-1	±0.25% to 20 kG	0 °C to +75 °C	±0.1 G/°C	–0.05%/°C

Tangential.eps

Figure 5-7. Definition of Lake Shore Tangential Probe

AXIAL PROBES

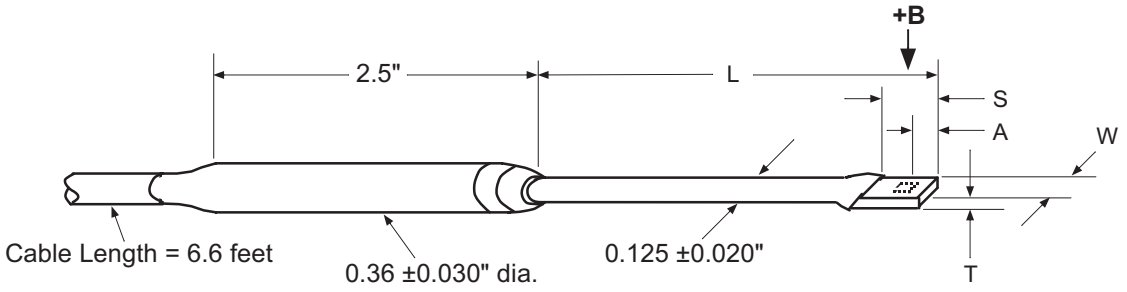


Model	L	D	A	Active Area	Stem Material	Freq. Range	Type	Corrected Accuracy (% Reading)	Op. Temp. Range	Temp. Coefficient (Max.)	
										Zero	Calibration
MMA-0602-TH	2 ±0.125"	0.060 dia. +0.001 -0.003"	0.005 ± 0.003"	0.020" dia. approx.	Alum.	DC, 10 to 400 Hz	HST-2	±0.25% to 10 kG	0 °C to 75 °C	±0.13 G per °C	±0.01% per °C
MMA-0604-TH	4 ±0.125"										
MMA-0608-TH	8 ±0.125"										
MMA-0618-TH	18 ±0.125"										
MMA-0802-UH	2 ±0.125"	0.080" dia. ±0.005"	0.010"			DC		±0.25% to 20 kG			
MMA-0804-UH	4 ±0.125"										
MMA-0808-UH	8 ±0.125"										
MNA-1902-VH	2 ±0.125"	0.187 dia. ±0.005"	0.005 ± 0.003"	0.030" dia. approx.	Fiber-glass Epoxy	DC, 10 to 400 Hz	HSE-1	±0.25% to 30 kG		±0.09 G per °C	±0.015% per °C
MNA-1904-VH	4 ±0.125"										
MNA-1908-VH	8 ±0.125"										
MMA-1802-VH	2 ±0.063"	0.180 dia. +0.002 -0.004"	0.016 ± 0.005"		Alum.						
MMA-1808-VH	8 ±0.125"										
MMA-1818-VH	18 ±0.25"										
MMA-1836-VH	36 ±0.25"										
MMA-2502-VH	2 ±0.063"	0.25 dia. ±0.006"									
MMA-2508-VH	8 ±0.125"										
MNA-1902-VG	2 ±0.125"	0.187 dia. ±0.005"	0.016 ± 0.005"		Fiber-glass Epoxy		HST-2	0.15% to 30 kG		±0.13 G per °C	–0.005% per °C
MNA-1904-VG	4 ±0.125"										
MNA-1908-VG	8 ±0.125"										
MMA-1802-VG	2 ±0.063"	0.180 dia. +0.002 –0.004"			Alum.						
MMA-1808-VG	8 ±0.125"										
MMA-1818-VG	18 ±0.25"										
MMA-1836-VG	36 ±0.25"										
MMA-2502-VG	2 ±0.063"	0.25 dia. ±0.006"									
MMA-2508-VG	8 ±0.125"										
MMA-1808-WL	8 ±0.125"	0.180 dia. +0.002 –0.004"					HST-1	±1% to 100 kG			
MMA-2536-WL	36 ±0.25"	0.25 dia. ±0.006"				DC					
MCA-2560-WN	60 ±0.50"	0.25 dia. ±0.005"	0.025 ±0.005"		Stainless Steel			±2% to 100 kG	1.5 K to 350 K		±0.010% per °C

Axial.eps

Figure 5-8. Definition of Lake Shore Axial Probes

FLEXIBLE TRANSVERSE PROBES



This table is for L = 3 inches and S = 0.375 inch

Model No.	W	T	A	Active Area	Stem Material	Frequency Range	Type	Corrected Accuracy (% of Reading)	Operating Temperature Range	Temperature Coefficient (maximum)	
										Zero	Calibration
MFT-3E03-VH	0.135" max	0.025" max	0.125" ±0.005"	0.040" dia. approx.	Flexible Tubing	DC, 10 to 400 Hz	HSE-1	±0.25% to 30 kG	0 °C to 75 °C	±0.09 G/°C	±0.015%/°C
MFT-3E03-VG							HST-2	±0.15% to 30 kG		±0.13 G/°C	–0.005%/°C
MFT-2903-VJ	0.085" max	0.020" max	0.065" ±0.005"	0.030" dia. approx.			HSE-1	±0.50% to 30 kG		±0.09 G/°C	±0.015%/°C
MFT-2903-VH							HST-2	±0.25% to 30 kG		±0.13 G/°C	–0.005%/°C

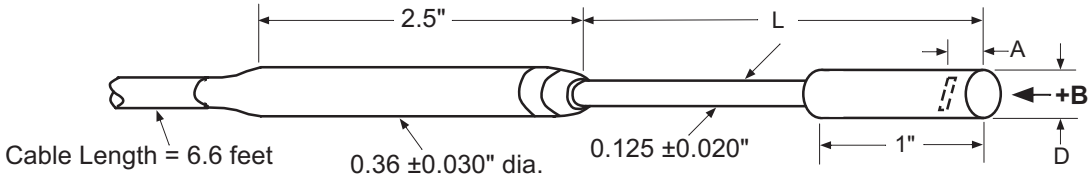
This table is for L = 15 ±0.5 inches and S = 0.75 inch

MFT-4F15-VH	0.150" ±0.005"	0.045" max	0.150" ±0.050"	0.040" dia. approx.	Flexible Tubing & Epoxy Fiber-glass	DC, 10 to 400 Hz	HSE-1	±0.25% to 30 kG	0 °C to 75 °C	±0.09 G/°C	±0.015%/°C
MFT-4F15-VG							HST-2	±0.15% to 30 kG		±0.13 G/°C	–0.005%/°C

Flexible_Transverse.eps

Figure 5-9. Definition of Lake Shore Flexible Transverse Probes

FLEXIBLE AXIAL PROBE



Model No.	L	D	A	Active Area	Stem Material	Frequency Range	Type	Corrected Accuracy (% of Reading)	Operating Temperature Range	Temperature Coefficient (max.)	
										Zero	Calibration
MFA-1815-VH	15" ±0.5"	0.025" max	0.125" ±0.005"	0.040" dia. approx.	Flexible Tubing	DC, 10 to 400 Hz	HSE-1	±0.25% to 30 kG	0 °C to 75 °C	±0.09 G/°C	±0.015%/°C

Flexible_Axial.eps

Figure 5-10. Definition of Lake Shore Flexible Axial Probe

5.4 HELMHOLTZ COIL LOW FIELD STANDARDS

Lake Shore offers three Helmholtz coils: 2.5-, 6-, and 12-inch diameter. Check the latest Lake Shore brochures or our website for any recent additions to this line.

These coils are accurately calibrated using field standards maintained at Lake Shore. Most standards are traceable to physical standards such as a coil of carefully controlled dimensions, or in some cases, to proton resonance. The field strengths are measured on the basis of the field generated by a current through the coil.

When combined with a customer-supplied power supply, these coils can be used as low-field reference magnets to compliment our set of standard reference magnets (defined in Paragraph 5.4). The power supply must be capable of 2 A output and a constant-current mode is recommended.

	MH-2.5	MH-6	MH-12
Inside Diameter	2.5 inches	6 inches	12 inches
Field Accuracy	±0.5%		
Field Strength	≈30 G @ 1 A	≈25 G @ 1 A	≈12 G @ 1 A
Field Homogeneity	0.5% within a cylindrical volume 0.75" long, 0.75" diameter, located at center of coil	0.5% within a cylindrical volume 1.6" long, 1.6" diameter, located at center of coil	0.5% within a cylindrical volume 3.2" long, 3.2" diameter, located at center of coil
Coil Resistance/Inductance	≈3 Ω / 6.3 mH	≈10 Ω / 36 mH	≈20 Ω / 93 mH
Maximum Continuous Current	2 A DC or AC RMS		
Operating Temperature Range	10 to 40 °C (50 to 104 °F)		

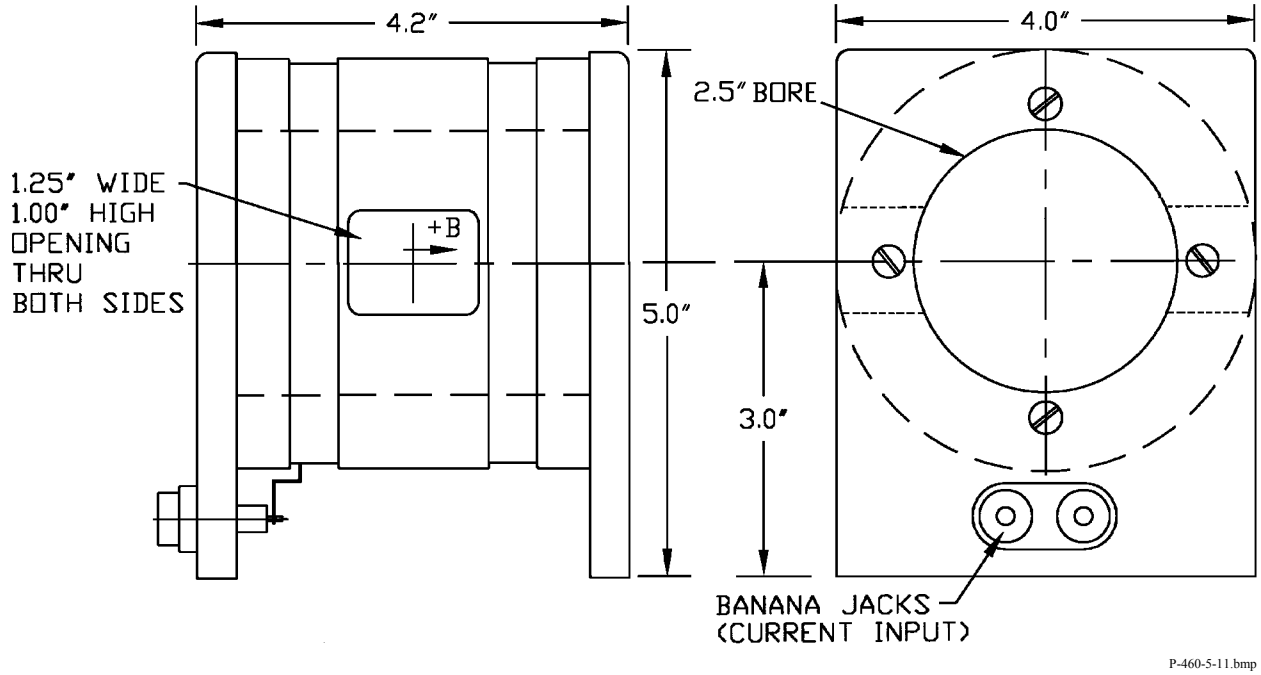


Figure 5-11. Model MH-2.5 Helmholtz Coil

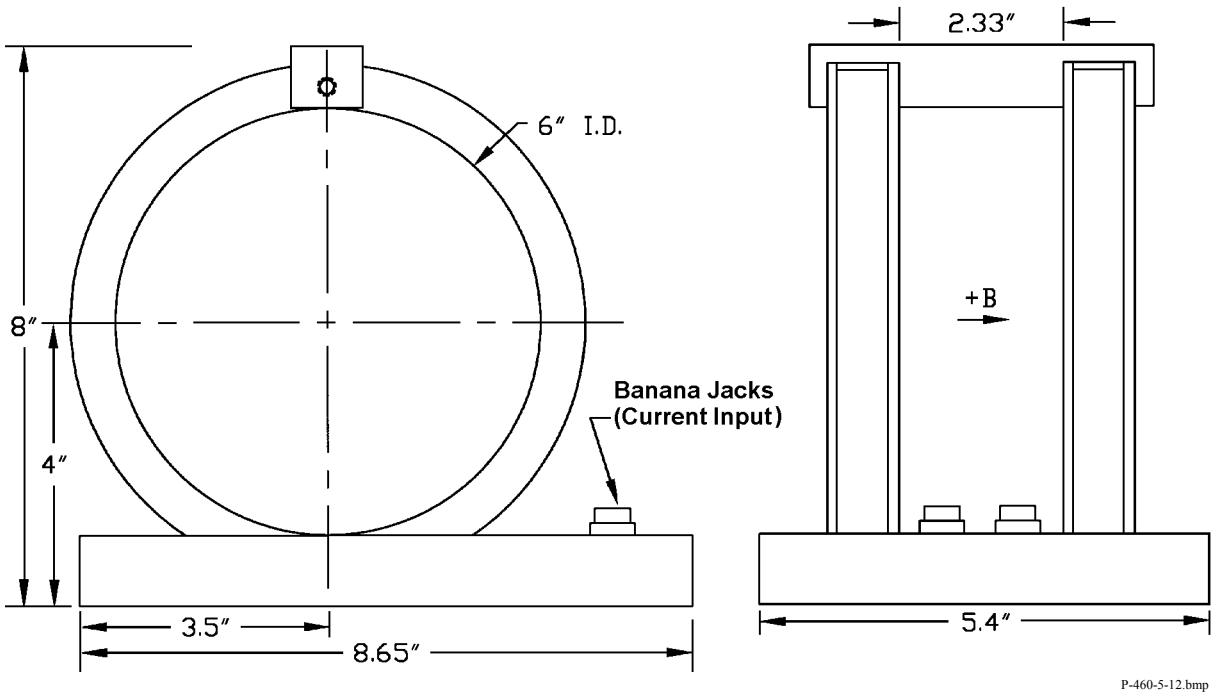


Figure 5-12. Model MH-6 Helmholtz Coil

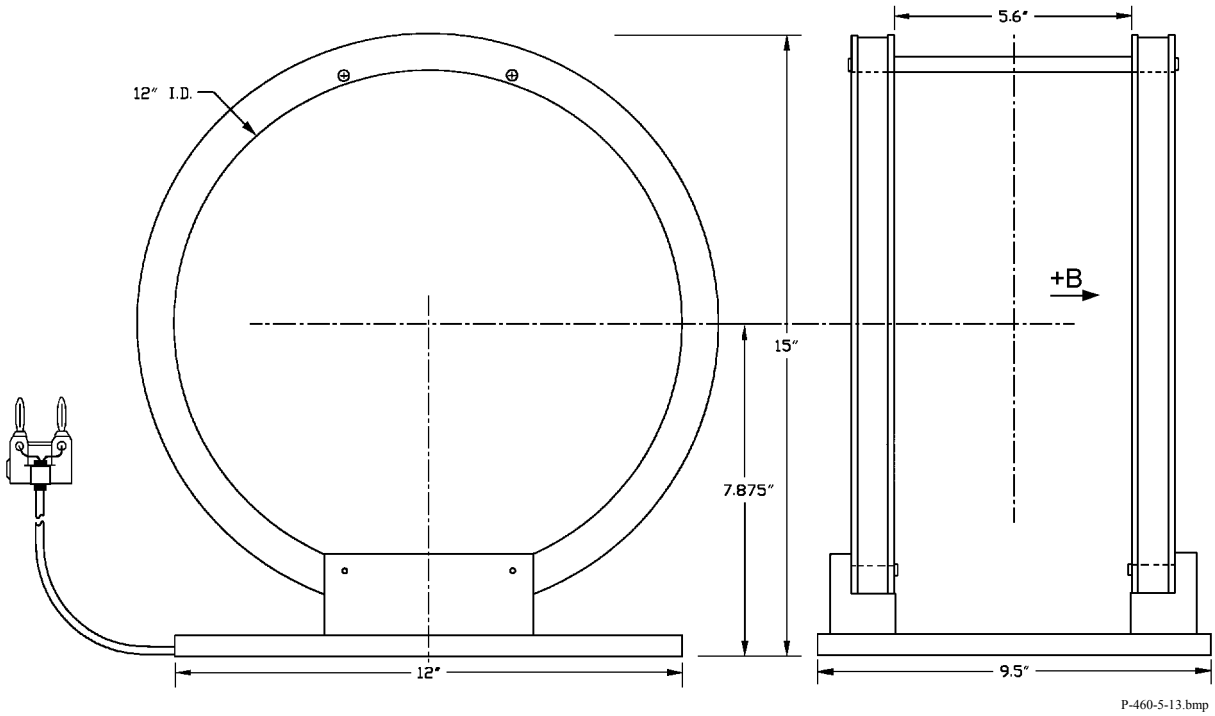


Figure 5-13. Model MH-12 Helmholtz Coil

5.5 REFERENCE MAGNETS

Magnetic reference standards containing highly stable permanent magnets have been in use for many years. The highest quality units are usually shielded from external magnetic effects and use Alnico V or VI magnets for long-term stability. They are supplied in both transverse (flat) and axial configurations.

Typical transverse reference magnets are usually stabilized for use at ambient temperatures between 0 – 50 °C and have nominal temperature coefficients of about –0.02%/°C. Because the temperature coefficient is negative, the field strength will be reduced as the temperature rises. Since these references are temperature cycled during manufacture, their change with temperature is predictable and retraceable; they will always return to a known value at any specific ambient temperature.

The high-permeability shell which surrounds the reference magnet serves two function: (1) it shields the magnet from external field, and (2) serves as the flux return path. Physical damage to the outer shell can cause a permanent change in the gap flux density. Reference magnets should not be dropped or physically abused. Magnets of this type can have magnetic reference values ranging from 100 G to 20 kG, but the most widely-used value is 1 kG. Reference magnet accuracy is typically ±0.5%, except for magnets of 200 G or less; for these magnets, the limit of error is generally ±1%. The reference magnet gap is nominally 0.060 inch but may range from 0.040 to 0.250 inch for special units. The usable "plateau" in the reference gap generally encompasses an area of about 0.5 square inches.

In reference magnets used for axial field probes, Alnico V or VI is the usual magnet material, charged to saturation and stabilized down to a particular value. The same temperature coefficients hold true as in the transverse probe and the same care in handling must be observed. This assembly uses concentric mu-metal shield cans to protect the magnet from the effects of external magnetic field. Axial reference magnets are available in values up to 2 kG, with 500 G being the most widely-used value.

When a probe is inserted completely through the access guide, three distinct magnetic peaks will be observed on the gaussmeter. One peak occurs as the probe enters the magnet, a second (and greater) peak is observed as the midpoint is reached, and a third (smaller) peak is read as the probe leaves the magnet. The calibration point is the largest reading in the midpoint area. Its amplitude will be approximately twice that of the readings that occur where the probe enters or leaves the magnet.

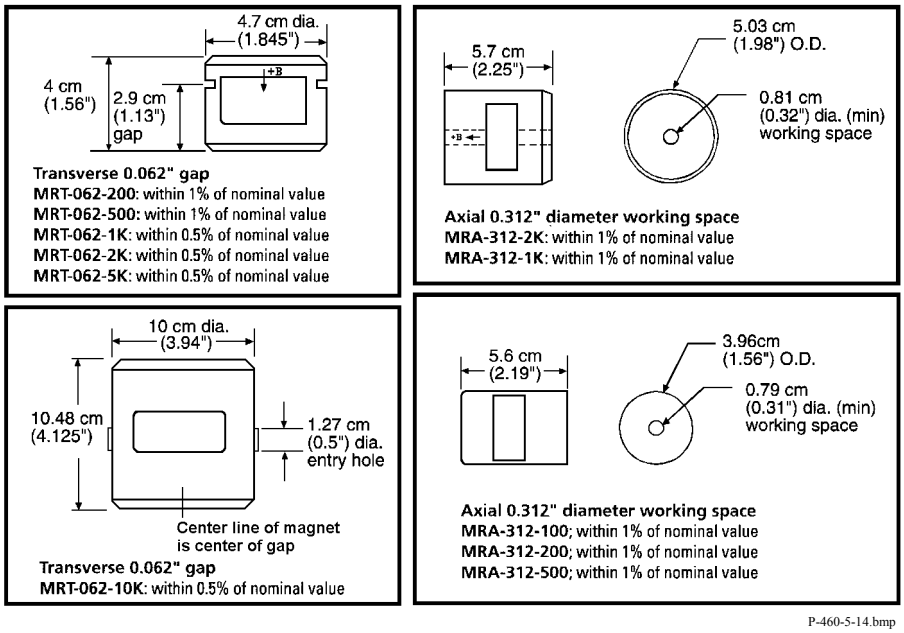


Figure 5-14. Lake Shore Reference Magnets

NOTE: Use care to ensure the Zero Gauss Chamber does not become magnetized. Using a magnetized chamber to zero a probe can lead to erroneous field readings. It is a good practice to periodically degauss the chamber. If no professional degausser is available, a bulk tape degausser (Verity VS250, Data Devices PF211, or equivalent) may be used.

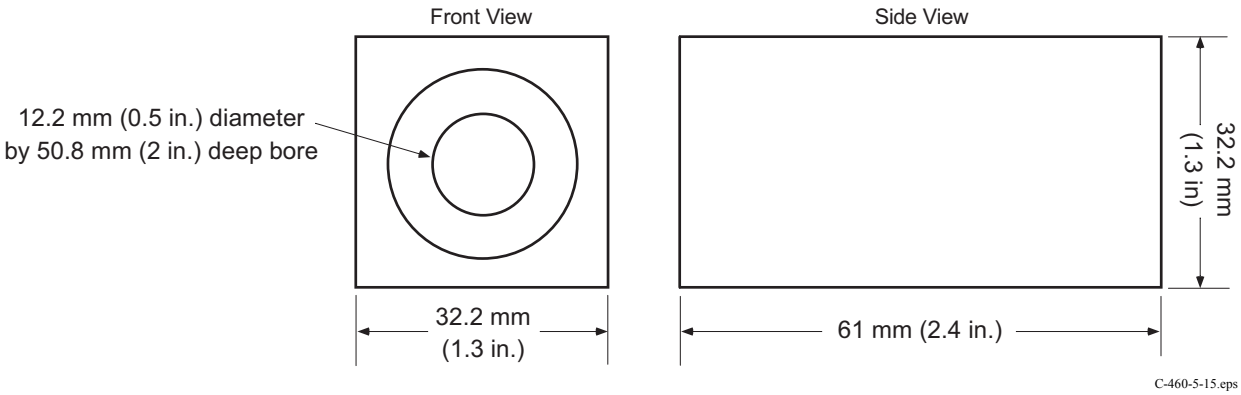


Figure 5-15. Model 4060 Zero Gauss Chamber

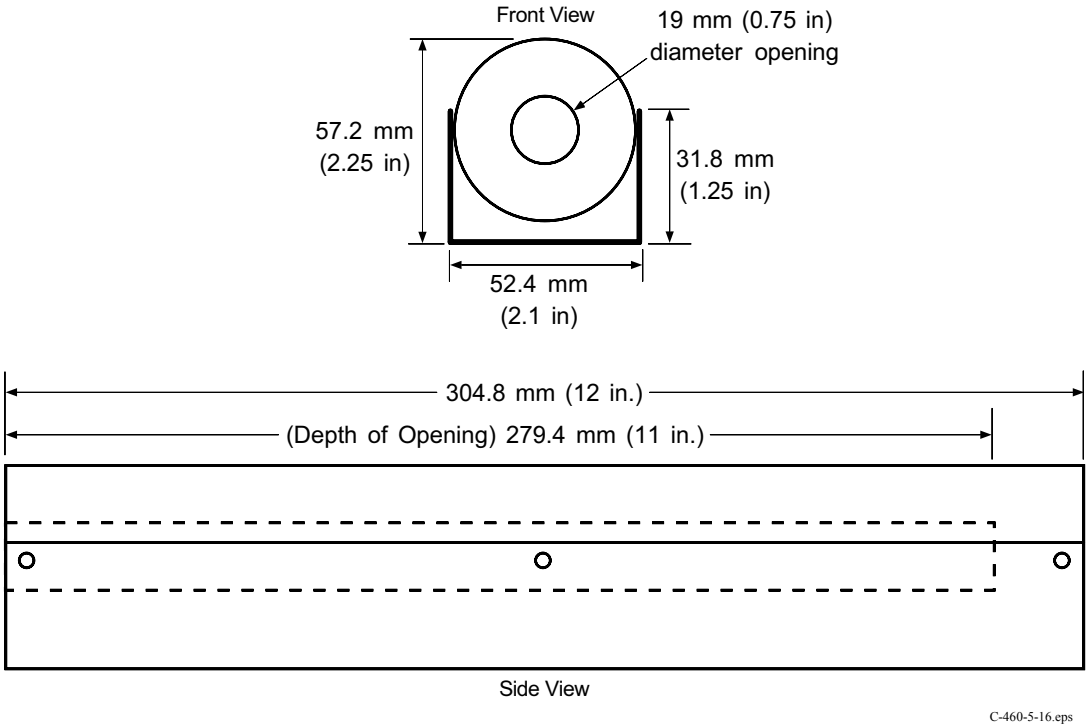
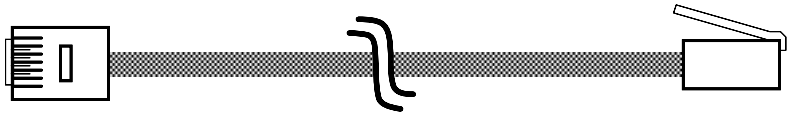


Figure 5-16. Model 4065 Large Zero Gauss Chamber

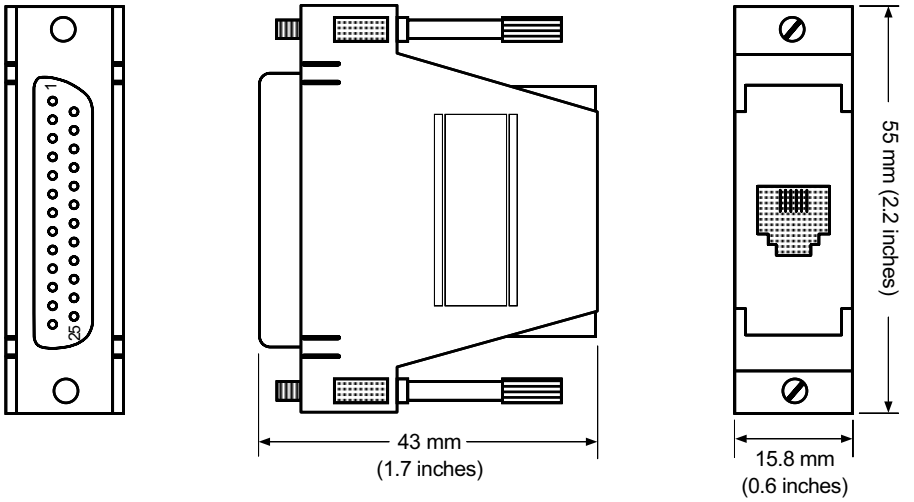


Cable Length: 4.3 meters (14 feet)

(See Figure 6-6 for wiring details.)

C-460-5-17.eps

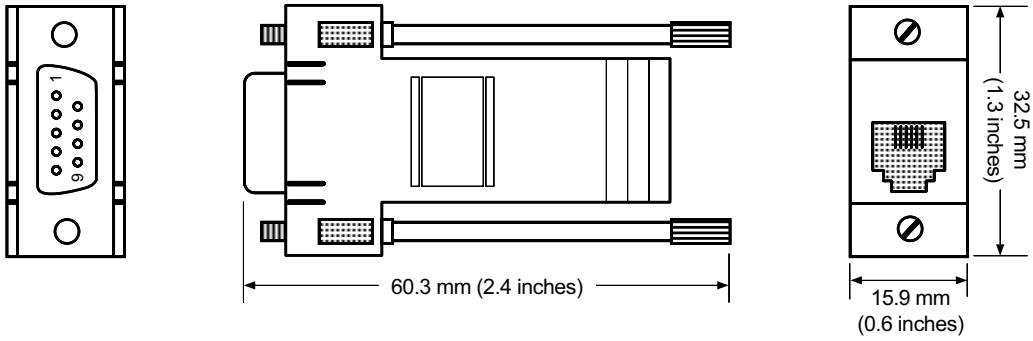
Figure 5-17. Model 4001 RJ-11 Cable Assembly



(See Figure 6-7 for wiring details.)

C-460-5-18.eps

Figure 5-18. Model 4002 RJ-11 to DB-25 Adapter



(See Figure 6-8 for wiring details.)

C-460-5-19.eps

Figure 5-19. Model 4003 RJ-11 to DE-9 Adapter

CHAPTER 6

SERVICE

6.0 GENERAL

This chapter covers general maintenance precautions in Paragraph 6.1, electrostatic discharge in Paragraph 6.2, line voltage selection in Paragraph 6.3, fuse replacement in Paragraph 6.4, rear panel connector definitions in Paragraph 6.5, optional serial interface cable and adapters in Paragraph 6.6, operating software EPROM replacement in Paragraph 6.7, and error messages in Paragraph 6.8.

There are no field serviceable parts inside the Model 460. Contact Lake Shore about specific problems with the Model 460.

6.1 GENERAL MAINTENANCE PRECAUTIONS

The following are general safety precautions unrelated to any other procedure in this publication. Keep away from live circuits. Installation personnel shall observe all safety regulations at all times. Turn off system power before making or breaking electrical connections. Regard any exposed connector, terminal board, or circuit board as a possible shock hazard. Discharge charged components only when such grounding results in no equipment damage. If a test connection to energized equipment is required, make the test equipment ground connection before probing the voltage or signal to be tested.

Do not install or service equipment alone. Do not reach into or adjust the equipment without having another person nearby capable of rendering aid.

If there is no power, verify the power cord is plugged into a live outlet and that both ends are securely plugged in. Next, check the fuse (refer to Paragraph 6.4).

Use this procedure to periodically clean the instrument to remove dust, grease, and other contaminants:

1. Clean front and back panels and case with soft cloth dampened with a mild detergent and water solution.

NOTE: Do *not* use aromatic hydrocarbons or chlorinated solvents to clean the instrument. They may react with the plastic materials used in the case or the silk screen printing on the back panel.

2. Clean the surface of printed circuit boards (PCBs) with clean, dry air at low pressure.

6.2 ELECTROSTATIC DISCHARGE

Electrostatic Discharge (ESD) may damage electronic parts, assemblies, and equipment. ESD is a transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact or induced by an electrostatic field. The low-energy source that most commonly destroys Electrostatic Discharge Sensitive (ESDS) devices is the human body, which generates and retains static electricity. Simply walking across a carpet in low humidity may generate up to 35,000 volts of static electricity.

Current technology trends toward greater complexity, increased packaging density, and thinner dielectrics between active elements, which results in electronic devices with even more ESD sensitivity. Some electronic parts are more ESDS than others. ESD levels of only a few hundred volts may damage electronic components such as semiconductors, thick and thin film resistors, and piezoelectric crystals during testing, handling, repair, or assembly. Discharge voltages below 4000 volts cannot be seen, felt, or heard.

6.2.1 Identification of Electrostatic Discharge Sensitive Components

The following are various industry symbols used to label components as ESDS.

6.2.2 Handling Electrostatic Discharge Sensitive Components

Observe all precautions necessary to prevent damage to ESDS components before attempting installation. Bring the device and everything that contacts it to ground potential by providing a conductive surface and discharge paths. As a minimum, observe these precautions:

1. De-energize or disconnect all power and signal sources and loads used with unit.
2. Place unit on a grounded conductive work surface.
3. Ground technician through a conductive wrist strap (or other device) using 1 MΩ series resistor to protect operator.
4. Ground any tools, such as soldering equipment, that will contact unit. Contact with operator's hands provides a sufficient ground for tools that are otherwise electrically isolated.
5. Place ESDS devices and assemblies removed from a unit on a conductive work surface or in a conductive container. An operator inserting or removing a device or assembly from a container must maintain contact with a conductive portion of the container. Use only plastic bags approved for storage of ESD material.
6. Do not handle ESDS devices unnecessarily or remove from the packages until actually used or tested.

6.3 LINE VOLTAGE SELECTION

Use the following procedure to change the instrument line voltage selector. Verify the fuse value whenever line voltage is changed.

WARNING: To avoid potentially lethal shocks, turn off gaussmeter and disconnect it from AC power before performing these procedures.

1. Identify the line input assembly on the instrument rear panel. See Figure 6-1.
2. Turn the line power switch OFF (**O**).
3. Remove the instrument power cord.
4. With a small screwdriver, release the drawer holding the line voltage selector and fuse.
5. Slide out the removable plastic fuse holder from the drawer.
6. Rotate the fuse holder until the proper voltage indicator shows through the window.
7. Verify the proper fuse value.
8. Re-assemble the line input assembly in the reverse order.
9. Verify the voltage indicator in the window of the line input assembly.
10. Connect the instrument power cord.
11. Turn the line power switch On (**I**).

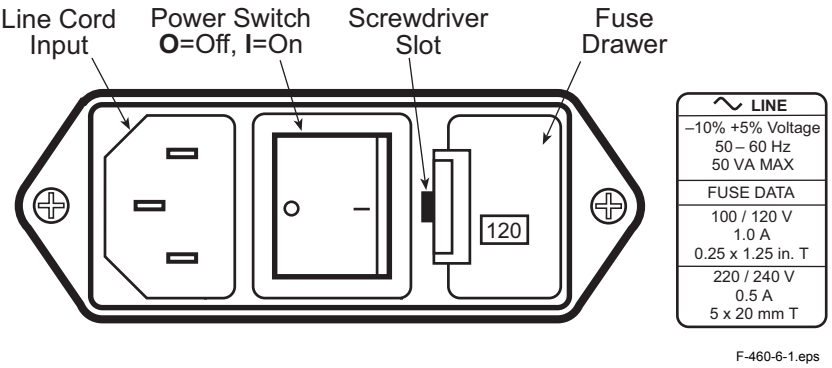


Figure 6-1. Power Fuse Access

6.4 FUSE REPLACEMENT

Below is the procedure to remove and replace a line fuse. There are two basic power configurations: U.S. and International. Units produced for use in the U.S. have a single fuse on the hot. Units produced for International use have a double fuse for the hot and neutral. To change line input from the factory setting, use the appropriate fuse in the connector kit shipped with the instrument. Test fuse with ohmmeter. Do not rely on visual inspection of fuse.

WARNING: To avoid potentially lethal shocks, turn off gaussmeter and disconnect it from AC power before performing these procedures.

CAUTION: For continued protection against fire hazard, replace only with the same fuse type and rating specified for the line for the line voltage selected.

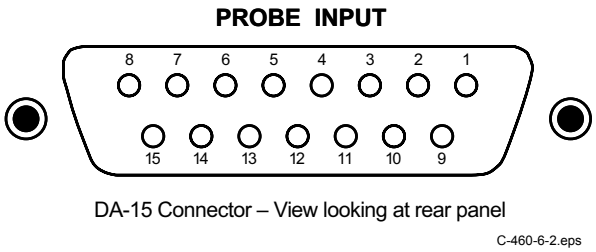
1. Locate line input assembly on the instrument rear panel. See Figure 6-1.
2. Turn power switch Off (**O**).
3. Remove instrument power cord.
4. With a small screwdriver, release the drawer holding the line voltage selector and fuse.
5. Remove existing fuse(s). Replace with proper Slow-Blow fuse ratings as follows:

100/120 V	1 A T 250 V	0.25 x 1.25 inches
220/240 V	0.5 A T 250 V	5 x 20 mm

6. Re-assemble line input assembly in reverse order.
7. Verify voltage indicator in the line input assembly window.
8. Connect instrument power cord.
9. Turn power switch On (**I**).

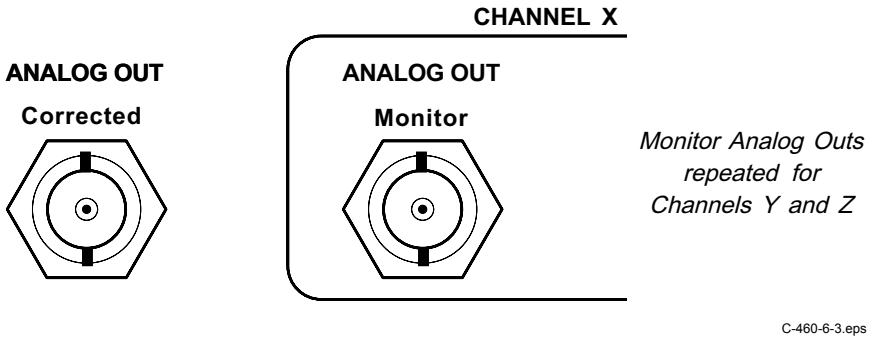
6.5 REAR PANEL CONNECTOR DEFINITIONS

The connectors on the rear panel of the Model 460 Gaussmeter are detailed in Figures 6-2 thru 6-4. Additional details for the IEEE-488 connector is provided in Paragraph 6.5.1.



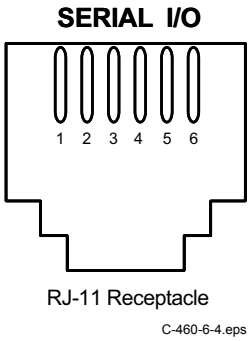
PIN	DESCRIPTION
1	Input + (Analog Signal)
2	No Connection
3	No Connection
4	ITEMP +
5	ITEMP –
6	No Connection
7	No Connection
8	I_C +
9	Input – (Analog Signal Ground)
10	No Connection
11	Digital Ground
12	+5 Volts (Power Output To Probe EEPROM)
13	EE-CLK (Output To Probe EEPROM)
14	EE-DATA (Serial Input From Probe EEPROM)
15	I_C –

Figure 6-2. PROBE INPUT Connector Details



PIN	DESCRIPTION
1	Analog Output – Center Conductor
2	Ground – Connector Shell

Figure 6-3. ANALOG OUT Corrected and Monitor BNC Connector Details



PIN	DESCRIPTION
1	Serial In (RxD)
2	Serial In (RxD)
3	Serial Ground
4	Serial Ground
5	Serial Out (TxD)
6	Serial Out (TxD)

Figure 6-4. SERIAL I/O Connector Details

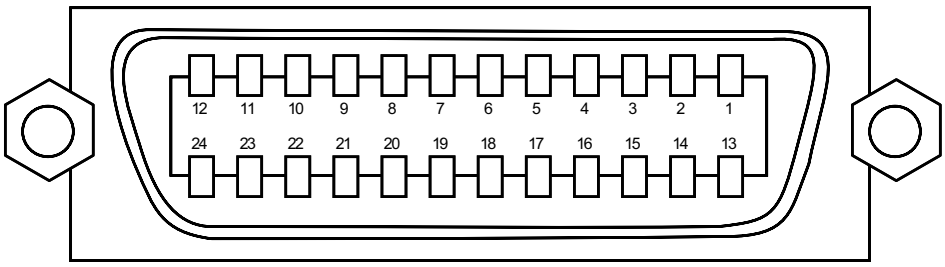
6.5.1 IEEE-488 INTERFACE CONNECTOR

Connect to the IEEE-488 Interface connector on the Model 460 rear with cables specified in the IEEE-488-1978 standard document. The cable has 24 conductors with an outer shield. The connectors are 24-way Amphenol 57 Series (or equivalent) with piggyback receptacles to allow daisy-chaining in multiple device systems. The connectors are secured in the receptacles by two captive locking screws with metric threads.

The total length of cable allowed in a system is 2 meters for each device on the bus, or 20 meters maximum. A system may be composed of up to 15 devices. Figure 6-5 shows the IEEE-488 Interface connector pin location and signal names as viewed from the Model 460 rear panel.

IEEE-488 INTERFACE

SH1 AH1 T5 L4 SR1 RL1 PP0 DC1 DT0 C0 E1



C-460-6-5.eps

PIN	*SYMBOL*	*DESCRIPTION*
1	DIO1	Data Input/Output Line 1
2	DIO2	Data Input/Output Line 2
3	DIO3	Data Input/Output Line 3
4	DIO4	Data Input/Output Line 4
5	EOI	End Or Identify
6	DAV	Data Valid
7	NRFD	Not Ready For Data
8	NDAC	Not Data Accepted
9	IFC	Interface Clear
10	SRQ	Service Request
11	ATN	Attention
12	SHIELD	Cable Shield
13	DIO5	Data Input/Output Line 5
14	DIO6	Data Input/Output Line 6
15	DIO7	Data Input/Output Line 7
16	DIO8	Data Input/Output Line 8
17	REN	Remote Enable
18	GND 6	Ground Wire – Twisted pair with DAV
19	GND 7	Ground Wire – Twisted pair with NRFD
20	GND 8	Ground Wire – Twisted pair with NDAC
21	GND 9	Ground Wire – Twisted pair with IFC
22	GND 10	Ground Wire – Twisted pair with SRQ
23	GND11	Ground Wire – Twisted pair with ATN
24	GND	Logic Ground

Figure 6-5. IEEE-488 Rear Panel Connector Details

6.6 OPTIONAL SERIAL INTERFACE CABLE AND ADAPTERS

To aid in Serial Interface troubleshooting, Figures 6-6 thru 6-8 show wiring information for the optional cable assembly and the two mating adapters.

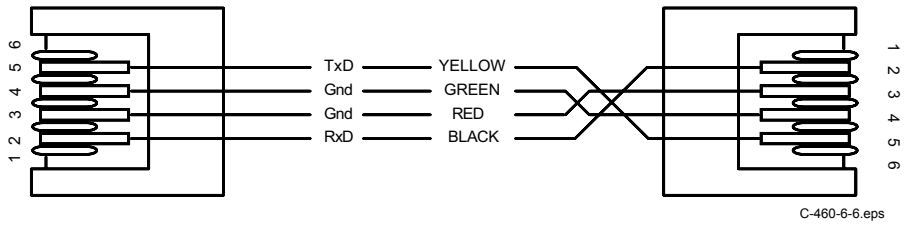


Figure 6-6. Model 4001 RJ-11 Cable Assembly Wiring Details

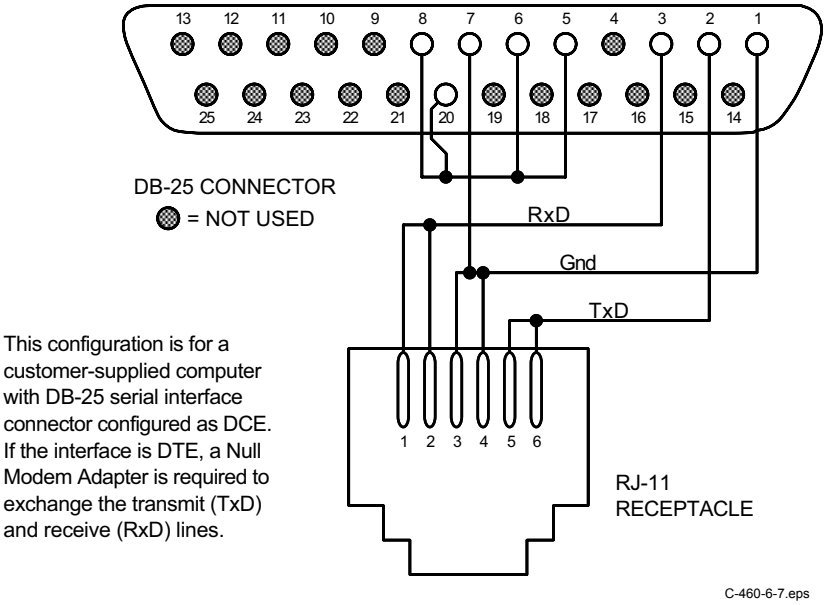

13 12 11 10 9 8 7 6 5 4 3 2 1
25 24 23 22 21 20 19 18 17 16 15 14
DB-25 CONNECTOR
= NOT USED
RxD
Gnd
TxD
This configuration is for a customer-supplied computer with DB-25 serial interface connector configured as DCE. If the interface is DTE, a Null Modem Adapter is required to exchange the transmit (TxD) and receive (RxD) lines.
1 2 3 4 5 6
RJ-11
RECEPTACLE
C-460-6-7.eps

Figure 6-7. Model 4002 RJ-11 to DB-25 Adapter Wiring Details

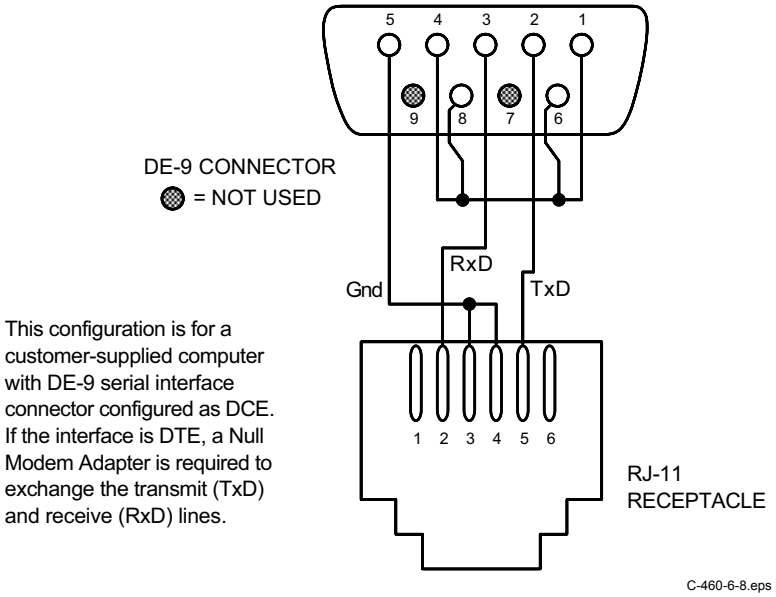

5 4 3 2 1
9 8 7 6
DE-9 CONNECTOR
= NOT USED
RxD
Gnd
TxD
This configuration is for a customer-supplied computer with DE-9 serial interface connector configured as DCE. If the interface is DTE, a Null Modem Adapter is required to exchange the transmit (TxD) and receive (RxD) lines.
1 2 3 4 5 6
RJ-11
RECEPTACLE
C-460-6-8.eps

Figure 6-8. Model 4003 RJ-11 to DE-9 Adapter Wiring Details

6.7 OPERATING SOFTWARE EPROM REPLACEMENT

The operating software for the Model 460 is contained on one Erasable Programmable Read Only Memory (EPROM) Integrated Circuit (IC). The EPROM is numbered U36 and located just behind the microprocessor IC (U31). The EPROM also has a label on top identifying the software version and date (see Figure 6-9). Use the procedure below to replace the operating software EPROM.

WARNING: To avoid potentially lethal shocks, turn off the instrument and disconnect it from the AC power line before performing this procedure.

1. Set power switch to Off and disconnect power cord from rear of unit.
2. If attached, remove 19-inch rack mounting brackets.
3. Use Phillips screwdriver to remove two flat-head screws from center rear top and bottom of enclosure.
4. Use 5/64 hex key to remove four screws attaching top panel to unit.
5. Use 5/64 hex key to loosen two rear bottom panel screws that secure the back plastic bezel.
6. Carefully remove back plastic bezel by sliding it straight back away from the unit.
7. Slide top panel back and remove from unit.
8. Locate software EPROM U95 on main circuit board. Note its orientation (circular notch on front of IC). See Figure 6-9.
9. Use IC puller to remove existing EPROM from socket.
10. Use IC insertion tool to place new EPROM into socket, noting its orientation.
11. Replace top of enclosure.
12. Replace back bezel and use 5/64 hex key to tighten two rear bottom panel screws to secure the bezel.
13. Use 5/64 hex key secure top of enclosure with four screws.
14. Use Phillips screwdriver to replace two flat-head screws to center rear top and bottom of enclosure.
15. Reconnect power cord to rear of unit and set power switch to On.
16. Perform the initial setup and system checkout (refer to Paragraph 2.7).

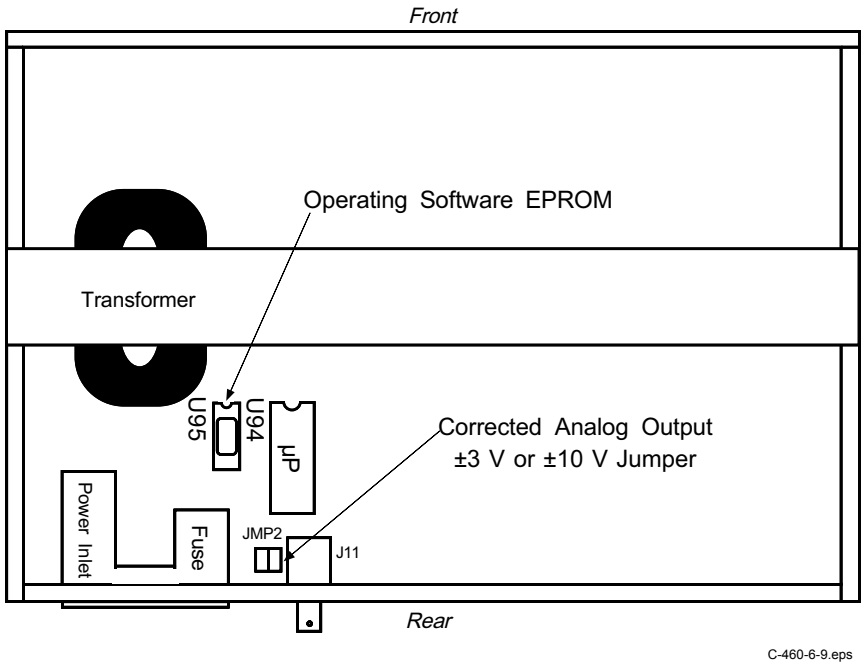


Figure 6-9. Location Of Operating Software EPROM

6.8 ERROR MESSAGES

The following is a list of Model 460 error messages that may be seen during normal operation.

OL	Field range has been exceeded. Refer to Paragraph 3.4 to change Range.
**** No Probe ****	No probe attached to the instrument at power up. Power the instrument off, attach a probe, and power it on again.
Locked	Keypad is locked to prevent accidental parameter changes. To unlock keypad refer to Paragraph 3.14.
Error 1	NOVRAM memory is physically malfunctioning. Contact Lake Shore service for repair.
Error2	NOVRAM memory is not initialized properly. Memory can be reinitialized as described in Paragraph 3.15. This operation will **not** restore calibration data that may have been corrupted. Instrument calibration should be checked after any Error 2 condition. Contact Lake Shore service for repair or calibration.

If the keyboard locks up, hold **Escape** for about 20 seconds to reset the Model 460 to factory defaults. The gaussmeter then requires the user to re-enter setpoints and zero the probe.

APPENDIX A

GLOSSARY OF TERMINOLOGY

accuracy. The degree of correctness with which a measured value agrees with the true value.[2]

electronic accuracy. The accuracy of an instrument independent of the sensor.

sensor accuracy. The accuracy of a temperature sensor and its associated calibration or its ability to match a standard curve.

algorithm. A set of well-defined rules for the solution of a problem in a finite number of steps.[1]

American Standard Code for Information Exchange (ASCII). A standard code used in data transmission, in which 128 numerals, letters, symbols, and special control codes are represented by a 7-bit binary number as follows:

Bits b_7 b_6 b_5 / b_4 b_3 b_2 b_1 / Row / Col.	0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
	0	1	2	3	4	5	6	7
0 0 0 0	0	NUL	DLE	SP	0	'	P	@	p
0 0 0 1	1	SOH	DC1	!	1	A	Q	a	q
0 0 1 0	2	STX	DC2	"	2	B	R	b	r
0 0 1 1	3	ETX	DC3	#	3	C	S	c	s
0 1 0 0	4	EOT	DC4	$	4	D	T	d	t
0 1 0 1	5	ENG	NAK	%	5	E	U	e	u
0 1 1 0	6	ACK	SYN	&	6	F	V	f	v
0 1 1 1	7	BEL	ETB	'	7	G	W	g	w
1 0 0 0	8	BS	CAN	(	8	H	X	h	x
1 0 0 1	9	HT	EM	)	9	I	Y	i	y
1 0 1 0	10	LF	SS	*	:	J	Z	j	z
1 0 1 1	11	VT	ESC	+	;	K	[	k	{
1 1 0 0	12	FF	FS	,	<	L	~	l	|
1 1 0 1	13	CR	GS	–	=	M	]	m	}
1 1 1 0	14	SO	RS	.	>	N	^	n	~
1 1 1 1	15	SI	US	/	?	O	_	o	DEL

American Wire Gage (AWG). Wiring sizes are defined as diameters in inches and millimeters as follows:

AWG	Dia. In.	Dia. mm	AWG	Dia. In.	Dia. mm	AWG	Dia. In.	Dia. mm	AWG	Dia. In.	Dia. mm
1	0.2893	7.348	11	0.0907	2.304	21	0.0285	0.7230	31	0.0089	0.2268
2	0.2576	6.544	12	0.0808	2.053	22	0.0253	0.6438	32	0.0080	0.2019
3	0.2294	5.827	13	0.0720	1.829	23	0.0226	0.5733	33	0.00708	0.178
4	0.2043	5.189	14	0.0641	1.628	24	0.0207	0.5106	34	0.00630	0.152
5	0.1819	4.621	15	0.0571	1.450	25	0.0179	0.4547	35	0.00561	0.138
6	0.1620	4.115	16	0.0508	1.291	26	0.0159	0.4049	36	0.00500	0.127
7	0.1443	3.665	17	0.0453	1.150	27	0.0142	0.3606	37	0.00445	0.1131
8	0.1285	3.264	18	0.0403	1.024	28	0.0126	0.3211	38	0.00397	0.1007
9	0.1144	2.906	19	0.0359	0.9116	29	0.0113	0.2859	39	0.00353	0.08969
10	0.1019	2.588	20	0.0338	0.8118	30	0.0100	0.2546	40	0.00314	0.07987

ampere. The constant current that, if maintained in two straight parallel conductors of infinite length, of negligible circular cross section, and placed one meter apart in a vacuum, would produce between these conductors a force equal to 2 x 10^{-7} newton per meter of length.[2] This is one of the base units of the SI.

ampere-turn. A MKS unit of magnetomotive force equal to the magnetomotive force around a path linking one turn of a conducting loop carrying a current of one ampere; or 1.26 gilberts.

ampere/meter (A/m). The SI unit for magnetic field strength (H). 1 ampere/meter = $4\pi/1000$ oersted $\approx$0.01257 oersted.

analog data. Data represented in a continuous form, as contrasted with digital data having discrete values.[1]

analog output. A voltage output from an instrument that is proportional to its input. From an instrument such as a digital voltmeter, the output voltage is generated by a digital-to-analog converter with a discrete number of voltage levels.

anode. The terminal that is positive with respect to the other terminal when the diode is biased in the forward direction.[2]

area. A measure of the size of a two-dimensional surface, or of a region on such a surface.[1]

area·turns. A coil parameter produced by the multiplication of the area of a magnet and number of turns. Gives an indication of the sensitivity of a coil.

B. Symbol for magnetic flux density. *See* Magnetic Flux Density.

baud. A unit of signaling speed equal to the number of discrete conditions or signal events per second, or the reciprocal of the time of the shortest signal element in a character.[2]

bit. A contraction of the term "binary digit"; a unit of information represented by either a zero or a one.[2]

calibration. To determine, by measurement or comparison with a standard, the correct (accurate) value of each scale reading on a meter or other device, or the correct value for each setting of a control knob.[1]

cathode. The terminal from which forward current flows to the external circuit.[2]

Celsius (°C) Scale. A temperature scale that registers the freezing point of water as 0 °C and the boiling point as 100 °C under normal atmospheric pressure. Celsius degrees are purely derived units, calculated from the Kelvin Thermodynamic Scale. Formerly known as "centigrade." *See* Temperature for conversions.

cgs system of units. A system in which the basic units are the centimeter, gram, and second.[2]

coercive force (coercive field). The magnetic field strength (H) required to reduce the magnetic induction (B) in a magnetic material to zero.

coercivity. generally used to designate the magnetic field strength (H) required to reduce the magnetic induction (B) in a magnetic material to zero from saturation. The coercivity would be the upper limit to the coercive force.

compliance voltage. *See* current source.

Curie temperature (Tc). Temperature at which a magnetized sample is completely demagnetized due to thermal agitation. Named for Pierre Curie (1859–1906), a French chemist.

current source. A type of power supply that supplies a constant current through a variable load resistance by automatically varying its compliance voltage. A single specification given as "compliance voltage" means the output current is within specification when the compliance voltage is between zero and the specified voltage.

demagnetization. when a sample is exposed to an applied field (H_a), poles are induced on the surface of the sample. Some of the returned flux from these poles is inside of the sample. This returned flux tends to decrease the net magnetic field strength internal to the sample yielding a true internal field (H_{int}) given by: $H_{int} = H_a - DM$,where M is the volume magnetization and D is the demagnetization factor. D is dependent on the sample geometry and orientation with respect to the field.

deviation. The difference between the actual value of a controlled variable and the desired value corresponding to the setpoint.[1]

differential permeability. The slope of a B versus H curve: $\mu_d = dB/dH$.

differential susceptibility. The slope of a M versus H curve: $\chi_d = dM/dH$.

digital controller. A feedback control system where the feedback device (sensor) and control actuator (heater) are joined by a digital processor. In Lake Shore controllers the heater output is maintained as a variable DC current source.

digital data. Pertaining to data in the form of digits or interval quantities. Contrast with analog data.[2]

dimensionless sensitivity. Sensitivity of a physical quantity to a stimulus, expressed in dimensionless terms. The dimensionless temperature sensitivity of a resistance temperature sensor is expressed as $S_d = (T/R)(dR/dT)$ which is also equal to the slope of R versus T on a log-log plot, that is $S_d = d\ lnR / d\ lnT$. Note that the absolute temperature (in kelvin) must be used in these expressions.

drift, instrument. An undesired but relatively slow change in output over a period of time, with a fixed reference input. *Note:* Drift is usually expressed in percent of the maximum rated value of the variable being measured.[2]

dynamic data exchange (DDE). A method of interprocess communication which passes data between processes and synchronized events. DDE uses shared memory to exchange data between applications and a protocol to synchronize the passing of data.

dynamic link library (DLL). A module that contains code, data, and Windows resources that multiple Windows programs can access.

electromagnet. A device in which a magnetic field is generated as the result of electrical current passing through a helical conducting coil. It can be configured as an iron-free solenoid in which the field is produced along the axis of the coil, or an iron-cored structure in which the field is produced in an air gap between pole faces. The coil can be water cooled copper or aluminum, or superconductive.

electron. An elementary particle containing the smallest negative electric charge. *Note:* The mass of the electron is approximately equal to 1/1837 of the mass of the hydrogen atom.[2]

electrostatic discharge (ESD). A transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact or induced by an electrostatic field.

error. Any discrepancy between a computed, observed, or measured quantity and the true, specified, or theoretically correct value or condition.[2]

Fahrenheit (°F) Scale. A temperature scale that registers the freezing point of water as 32 °F and the boiling point as 212 °F under normal atmospheric pressure. *See* Temperature for conversions.

flux (ϕ). The electric or magnetic lines of force in a region.[1]

gamma. A cgs unit of low-level flux density, where 100,000 gamma equals one gauss, or 1 gamma equals 10^{-5} gauss.

gauss (G). The cgs unit for magnetic flux density (B). 1 gauss = 10^{-4} tesla = 1 Mx/cm^2 = $line/cm^2$. Named for Karl Fredrich Gauss (1777–1855) a German mathematician, astronomer, and physicist.

gaussian system (units). A system in which centimeter-gram-second units are used for electric and magnetic qualities.

general purpose interface bus (GPIB). Another term for the IEEE-488 bus.

gilbert (Gb). A cgs electromagnetic unit of the magnetomotive force required to produce one maxwell of magnetic flux in a magnetic circuit of unit reluctance. One gilbert is equal to $10/4\pi$ ampere-turn. Named for William Gilbert (1540–1603), an English physicist who hypothesized that the Earth is a magnet.

gilbert per centimeter. Practical cgs unit of magnet intensity. Gilberts per cm are the same as oersteds.

Greek alphabet. The Greek alphabet is defined as follows:

Alpha	α	A	Iota	ι	I	Rho	ρ	P
Beta	β	B	Kappa	κ	K	Sigma	σ	Σ
Gamma	γ	Γ	Lambda	λ	Λ	Tau	τ	T
Delta	δ	Δ	Mu	μ	M	Upsilon	υ	Y
Epsilon	ε	E	Nu	ν	N	Phi	ϕ	Φ
Zeta	ζ	Z	Xi	ξ	Ξ	Chi	χ	X
Eta	η	H	Omicron	ο	O	Psi	ψ	Ψ
Theta	θ	Θ	Pi	π	Π	Omega	ω	Ω

ground. A conducting connection, whether intentional or accidental, by which an electric circuit or equipment is connected to the earth, or to some conducting body of large extent that serves in place of the earth. *Note:* It is used for establishing and maintaining the potential of the earth (or of the conducting body) or approximately that potential, on conductors connected to it, and for conducting ground current to and from the earth (or of the conducting body).[2]

H. Symbol for magnetic field strength. *See* Magnetic Field Strength.

Hall effect. The generation of an electric potential perpendicular to both an electric current flowing along a thin conducting material and an external magnetic field applied at right angles to the current. Named for Edwin H. Hall (1855–1938), an American physicist.

Hall mobility. The quantity μ_H in the relation $\mu_H = R\sigma$, where R = Hall coefficient and σ = conductivity.[2]

Helmholtz coils. A pair of flat, circular coils having equal numbers of turns and equal diameters, arranged with a common axis, and connected in series; used to obtain a magnetic field more nearly uniform than that of a single coil.[1]

hertz (Hz). A unit of frequency equal to one cycle per second.

hole. A mobile vacancy in the electronic valence structure of a semiconductor that acts like a positive electron charge with a positive mass.[2]

hysteresis. The dependence of the state of a system on its previous history, generally in the form of a lagging of a physical effect behind its cause.[1] Also *see* magnetic hysteresis.

IEEE. Institute of Electrical and Electronics Engineers.

IEEE-488. An instrumentation bus with hardware and programming standards designed to simplify instrument interfacing. The addressable, parallel bus specification is defined by the IEEE.

initial permeability. The permeability determined at H = 0 and B = 0.

initial susceptibility. The susceptibility determined at H = 0 and M = 0.

integrator. A circuit or network whose output waveform is the time integral of its input waveform.[1]

international system of units (SI). A universal coherent system of units in which the following seven units are considered basic: meter, kilogram, second, ampere, kelvin, mole, and candela. The International System of Units, or Système International d'Unités (SI), was promulgated in 1960 by the Eleventh General Conference on Weights and Measures. For definition, spelling, and protocols, *see* Reference 3 for a short, convenient guide.

interpolation table. A table listing the output and sensitivity of a sensor at regular or defined points which may be different from the points at which calibration data was taken.

intrinsic coercivity. The magnetic field strength (H) required to reduce the magnetization (M) or intrinsic induction in a magnetic material to zero.

intrinsic induction. The contribution of the magnetic material (B_i) to the total magnetic induction (B).

$B_i = B - \mu_0 H$ (SI) $B_i = B - H$ (cgs)

isolated (neutral system). A system that has no intentional connection to ground except through indicating, measuring, or protective devices of very-high impedance.[2]

Kelvin (K). The unit of temperature on the Kelvin Scale. It is one of the base units of SI. The word "degree" and its symbol (°) are omitted from this unit. *See* Temperature Scale for conversions.

Kelvin Scale. The Kelvin Thermodynamic Temperature Scale is the basis for all international scales, including ITS-90. It is fixed at 2 points: the absolute zero of temperature (0 K), and the triple point of water (273.16 K), the equilibrium temperature that pure water reaches in the presence of ice and its own vapor.

line regulation. The maximum steady-state amount that the output voltage or current will change as the result of a specified change in input line voltage (usually for a step change between 105–125 or 210–250 volts, unless otherwise specified).

line of flux. An imaginary line in a magnetic field of force whose tangent at any point gives the direction of the field at that point; the lines are spaced so that the number through a unit area perpendicular to the field represents the intensity of the field. Also know as a Maxwell in the cgs system of units.

line voltage. The RMS voltage of the primary power source to an instrument.

load regulation. A steady-state decrease of the value of the specified variable resulting from a specified increase in load, generally from no-load to full-load unless otherwise specified.

M. Symbol for magnetization. *See* magnetization.

magnetic air gap. The air space, or non-magnetic portion, of a magnetic circuit.

magnetic field strength (H). The magnetizing force generated by currents and magnetic poles. For most applications, the magnetic field strength can be thought of as the applied field generated, for example, by a superconducting magnet. The magnetic field strength is not a property of materials. Measure in SI units of A/m or cgs units of oersted.

magnetic flux density (B). Also referred to as magnetic induction. This is the net magnetic response of a medium to an applied field, H. The relationship is given by the following equation: $B = \mu_0 (H + M)$ for SI, and $B = H + 4\pi M$ for cgs, where H = magnetic field strength, M = magnetization, and μ_0 = permeability of free space = $4\pi \times 10^{-7}$ H/m.

magnetic hysteresis. The property of a magnetic material where the magnetic induction (B) for a given magnetic field strength (H) depends upon the past history of the samples magnetization.

magnetic induction (B). *See* magnetic flux density.

magnetic moment (m). This is the fundamental magnetic property measured with dc magnetic measurements systems such as a vibrating sample magnetometer, extraction magnetometer, SQUID magnetometer, etc. The exact technical definition relates to the torque exerted on a magnetized sample when placed in a magnetic field. Note that the moment is a total attribute of a sample and alone does not necessarily supply sufficient information in understanding material properties. A small highly magnetic sample can have exactly the same moment as a larger weakly magnetic sample (*see* Magnetization). Measured in SI units as $A \cdot m^2$ and in cgs units as emu. 1 emu = 10^{-3} $A \cdot m^2$.

magnetic scalar potential. The work which must be done against a magnetic field to bring a magnetic pole of unit strength from a reference point (usually at infinity) to the point in question. Also know as magnetic potential.[1]

magnetic units. Units used in measuring magnetic quantities. Includes ampere-turn, gauss, gilbert, line of force, maxwell, oersted, and unit magnetic pole.

magnetization (M). This is a material specific property defined as the magnetic moment (m) per unit volume (V). M = m/V. Measured in SI units as A/m and in cgs units as emu/cm^3. 1 emu/cm^3 = 10^3 A/m. Since the mass of a sample is generally much easier to determine than the volume, magnetization is often alternately expressed as a mass magnetization defined as the moment per unit mass.

magnetostatic. Pertaining to magnetic properties that do not depend upon the motion of magnetic fields.[1]

mains. *See* line voltage.

Maxwell (Mx). A cgs electromagnetic unit of magnetic flux, equal to the magnetic flux which produces an electromotive force of 1 abvolt in a circuit of one turn link the flux, as the flux is reduced to zero in 1 second at a uniform rate.[1]

MKSA System of Units. A system in which the basic units are the meter, kilogram, and second, and the ampere is a derived unit defined by assigning the magnitude $4\pi \times 10^{-7}$ to the rationalized magnetic constant (sometimes called the permeability of space).

NBS. National Bureau of Standards. Now referred to as NIST.

National Institute of Standards and Technology (NIST). Government agency located in Gaithersburg, Maryland and Boulder, Colorado, that defines measurement standards in the United States. *See* Standards Laboratories for an international listing.

noise (electrical). Unwanted electrical signals that produce undesirable effects in circuits of control systems in which they occur.[2]

normalized sensitivity. For resistors, signal sensitivity (dR/dT) is geometry dependent; i.e., dR/dT scales directly with R; consequently, this sensitivity is often normalized by dividing by the measured resistance to give a sensitivity, s_T, in percent change per kelvin. s_T = (100/R) (dR/dT) %K, where T is temperature in kelvin and R is resistance in ohms.

normally closed (N.C.). A term used for switches and relay contacts. Provides a closed circuit when actuator is in the free (unenergized) position.

normally open (N.O.). A term used for switches and relay contacts. Provides an open circuit when actuator is in the free (unenergized) position.

oersted (Oe). The cgs unit for the magnetic field strength (H). 1 oersted = 10¾ π ampere/meter ≈ 79.58 ampere/meter.

ohm (Ω). The SI unit of resistance (and of impedance). The ohm is the resistance of a conductor such that a constant current of one ampere in it produces a voltage of one volt between its ends.[2]

pascal (Pa). The SI unit of pressure equal to 1 N/m^2. Equal to 1.45×10^{-4} psi, 1.0197×10^{-5} kg_f/cm^2, 7.5×10^{-3} torr, 4.191×10^{-3} inches of water, or 1×10^{-5} bar.

permeability. Material parameter which is the ratio of the magnetic induction (B) to the magnetic field strength (H): μ = B/H. Also *see* Initial Permeability and Differential Permeability.

polynomial fit. A mathematical equation used to fit calibration data. Polynomials are constructed of finite sums of terms of the form $a_i x_i$, where a_i is the i^{th} fit coefficient and x_i is some function of the dependent variable.

pounds per square inch (psi). A unit of pressure. 1 psi = 6.89473 kPa. Variations include psi absolute (psia) measured relative to vacuum (zero pressure) where one atmosphere pressure equals 14.696 psia and psi gauge (psig) where gauge measured relative to atmospheric or some other reference pressure.

ppm. Parts per million, e.g., 4 x 10^{-6} is four parts per million.

precision. Careful measurement under controlled conditions which can be repeated with similar results. *See* repeatability. Also means that small differences can be detected and measured with confidence. *See* resolution.

prefixes. SI prefixes used throughout this manual are as follows:

Factor	Prefix	Symbol	Factor	Prefix	Symbol
10^{24}	yotta	Y	10^{-1}	deci	d
10^{21}	zetta	Z	10^{-2}	centi	c
10^{18}	exa	E	10^{-3}	milli	m
10^{15}	peta	P	10^{-6}	micro	μ
10^{12}	tera	T	10^{-9}	nano	n
10^{9}	giga	G	10^{-12}	pico	p
10^{6}	mega	M	10^{-15}	femto	f
10^{3}	kilo	k	10^{-18}	atto	a
10^{2}	hecto	h	10^{-21}	zepto	z
10^{1}	deka	da	10^{-24}	yocto	y

probe. A long, thin body containing a sensing element which can be inserted into a system in order to make measurements. Typically, the measurement is localized to the region near the tip of the probe.

remanence. The remaining magnetic induction in a magnetic material when the material is first saturated and then the applied field is reduced to zero. The remanence would be the upper limit to values for the remanent induction. Note that no strict convention exists for the use of remanent induction and remanence and in some contexts the two terms may be used interchangeably.

remanent induction. The remaining magnetic induction in a magnetic material after an applied field is reduced to zero. Also *see* remanence.

repeatability. The closeness of agreement among repeated measurements of the same variable under the same conditions.[2]

resolution. The degree to which nearly equal values of a quantity can be discriminated.[2]

display resolution. The resolution of an instrument's physical display. This is not always the same as the measurement resolution of the instrument. Decimal display resolution specified as "n digits" has 10^n possible display values. A resolution of n and one-half digits has 2 x 10^n possible values.

measurement resolution. The ability of an instrument to resolve a measured quantity. For digital instrumentation this is often defined by the analog to digital converter being used. A n-bit converter can resolve one part in 2^n. The smallest signal change that can be measured is the full scale input divided by 2^n for any given range. Resolution should not be confused with accuracy.

root mean square (RMS). The square root of the time average of the square of a quantity; for a periodic quantity the average is taken over one complete cycle. Also known as effective value.[1]

RS-232C. Bi-directional computer serial interface standard defined by the Electronic Industries Association (EIA). The interface is single-ended and non-addressable.

scalar. A quantity which has magnitude only and no direction, in contrast to a vector.[1]

semiconducting material. A conducting medium in which the conduction is by electrons, and holes, and whose temperature coefficient of resistivity is negative over some temperature range below the melting point.[2]

semiconductor. An electronic conductor, with resistivity in the range between metals and insulators, in which the electric charge carrier concentration increases with increasing temperature over some temperature range. Note: Certain semiconductors possess two types of carriers, namely, negative electrons and positive holes.[2]

sensitivity. The ratio of the response or change induced in the output to a stimulus or change in the input. Temperature sensitivity of a resistance temperature detector is expressed as S = dR/dT.

setpoint. The value selected to be maintained by an automatic controller.[1]

serial interface. A computer interface where information is transferred one bit at a time rather than one byte (character) at a time as in a parallel interface. RS-232C is a common serial interface.

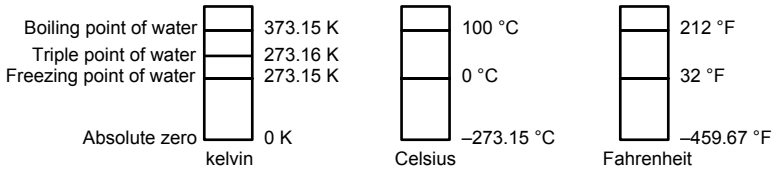
SI. Système International d'Unités. *See* International System of Units.

stability. The ability of an instrument or sensor to maintain a constant output given a constant input.

susceptance. In electrical terms, susceptance is defined as the reciprocal of reactance and the imaginary part of the complex representation of admittance: [suscept(ibility) + (conduct)ance].

susceptibility (χ). Parameter giving an indication of the response of a material to an applied magnetic field. The susceptibility is the ratio of the magnetization (M) to the applied field (H). χ = M/H. In both SI units and cgs units the volume susceptibility is a dimensionless parameter. Multiply the cgs susceptibility by 4π to yield the SI susceptibility. *See* also Initial Susceptibility and Differential Susceptibility. As in the case of magnetization, the susceptibility is often seen expressed as a mass susceptibility or a molar susceptibility depending upon how M is expressed.

temperature scales. *See* Kelvin Scale, Celsius Scale, and ITS-90. Proper metric usage requires that only kelvin and degrees Celsius be used. However, since degrees Fahrenheit is in such common use, all three scales are delineated as follows:



To convert kelvin to Celsius, subtract 273.15.

To convert Celsius to Fahrenheit: multiply °C by 1.8 then add 32, or: °F = (1.8 x °C) + 32.

To convert Fahrenheit to Celsius: subtract 32 from °F then divide by 1.8, or: °C = (°F. 32)/ 1.8.

temperature coefficient, measurement. The measurement accuracy of an instrument is affected by changes in ambient temperature. The error is specified as an amount of change (usually in percent) for every one degree change in ambient temperature.

tesla (T). The SI unit for magnetic flux density (B). 1 tesla = 10^4 gauss

thermal emf. An electromotive force arising from a difference in temperature at two points along a circuit, as in the Seebeck effect.[1]

tolerance. The range between allowable maximum and minimum values.

turns (N). One complete loop of wire.

Underwriters Laboratories (UL). An independent laboratory that establishes standards for commercial and industrial products.

unit magnetic pole. A pole with a strength such that when it is placed 1 cm away from a like pole, the force between the two is 1 dyne.

vector. A quantity that has both magnitude and direction, and whose components transform from one coordinate system to another in the same manner as the components of a displacement. Also known as a polar vector.[1]

volt (V). The difference of electric potential between two points of a conductor carrying a constant current of one ampere, when the power dissipated between these points is equal to one watt.[2]

volt-ampere (VA). The SI unit of apparent power. The volt-ampere is the apparent power at the points of entry of a single-phase, two-wire system when the product of the RMS value in amperes of the current by the RMS value in volts of the voltage is equal to one.[2]

volt·second (v·s). A voltage of 1 volt (V) present at the input of a fluxmeter for 1 second (s) results in a reading of 1 volt·second (v·s). Volt·seconds are the primary unit of measurement for an integrator. *See* Weber.

watt (W). The SI unit of power. The watt is the power required to do work at the rate of 1 joule per second.[2]

weber (Wb). The unit of magnetic flux in the mks system, equal to the magnetic flux which, linking a circuit of one turn, produces in it an electromotive force of 1 volt as it is reduced to zero at a uniform rate in 1 second.[1]

References:

1 Sybil P. Parker, Editor. *Dictionary of Scientific and Technical Terms: Fifth Edition*. New York: McGraw Hill, 1994 (IBSN 0-07-042333-4)

2 Christopher J. Booth, Editor. *The New IEEE Standard Dictionary of Electrical and Electronic Terms: IEEE Std 100-1992, Fifth Edition.* New York: Institute of Electrical and Electronics Engineers, 1993 (IBSN 1-55937-240-0). Definitions printed with permission of the IEEE.

3 Nelson, Robert A. *Guide For Metric Practice,* Page BG7 - 8, Physics Today, Eleventh Annual Buyer's Guide, August 1994 (ISSN 0031-9228 coden PHTOAD)

APPENDIX B

UNITS FOR MAGNETIC PROPERTIES

Table B-1. Conversion from CGS to SI Units

Quantity	*Symbol*	*Gaussian and CGS emu*[a]	*Conversion Factor, C*[b]	*SI and Rationalized mks*[c]
Magnetic flux density, Magnetic induction	B	gauss (G)[d]	10^{-4}	tesla (T), Wb/m^2
Magnetic Flux	ϕ	maxwell (Mx), $G \cdot cm^2$	10^{-8}	weber (Wb), volt second (V•s)
Magnetic potential difference, magnetomotive force	U, F	gilbert (Gb)	$10/4\pi$	ampere (A)
Magnetic field strength, magnetizing force	H	oersted (Oe),[e] Gb/cm	$10^3/4\pi$	A/m[f]
(Volume) magnetization[g]	M	emu/cm^3[h]	10^3	A/m
(Volume) magnetization	$4\pi M$	G	$10^3/4\pi$	A/m
Magnetic polarization, intensity of magnetization	J, I	emu/cm^3	$4\pi \times 10^{-4}$	T, Wb/m^2[i]
(Mass) magnetization	σ, M	emu/g	$\frac{1}{4\pi \times 10^{-7}}$	$A \cdot m^2/kg$ Wb•m/kg
Magnetic moment	m	emu, erg/G	10^{-3}	$A \cdot m^2$, joule per tesla (J/T)
Magnetic dipole moment	j	emu, erg/G	$4\pi \times 10^{-10}$	$Wb \cdot m$[i]
(Volume) susceptibility	χ, κ	dimensionless emu/cm^3	$\frac{\text{—}}{(4\pi)^2 \times 10^{-7}}$	Henry per meter (H/m), Wb/(A•m)
(Mass) susceptibility	χ_ρ, κ_ρ	cm^3/g, emu/g	$4\pi \times 10^{-3}$ $(4\pi)2 \times 10^{-10}$	m^3/kg $H \cdot m^2/kg$
(Molar) susceptibility	χ_{mol}, κ_{mol}	cm^3/mol, emu/mol	$4\pi \times 10^{-6}$ $(4\pi)^2 \times 10^{-13}$	m^3/mol $H \cdot m^2/mol$
Permeability	μ	dimensionless	$4\pi \times 10^{-7}$	H/m, Wb/(A•m)
Relative permeability[j]	μ_r	not defined	—	dimensionless
(Volume) energy density, energy product[k]	W	erg/cm^3	10^{-1}	J/m^3
Demagnetization factor	D, N	dimensionless	$1/4\pi$	dimensionless

NOTES:

a. Gaussian units and cgs emu are the same for magnetic properties. The defining relation is $B = H + 4\pi M$.

b. Multiply a number in Gaussian units by C to convert it to SI (e.g. $1\ G \times 10^{-4} T/G = 10^{-4} T$).

c. SI (Système International d'Unités) has been adopted by the National Bureau of Standards. Where two conversion factors are given, the upper one is recognized under, or consistent with, SI and is based on the definition $B = \mu_0(H + M)$, where to $\mu_0 = 4\pi \times 10^{-7} H/m$. The lower one is not recognized under SI and is based on the definition $B = \mu_0 H + J$, where the symbol I is often used in place of J.

d. 1 gauss = 10^5 gamma (γ).

e. Both oersted and gauss are expressed as $cm^{-½} \cdot g^{½} \cdot s^{-1}$ in terms of base units.

f. A/m was often expressed as "ampere-turn per meter" when used for magnetic field strength.

g. Magnetic moment per unit volume.

h. The designation "emu" is not a unit.

i. Recognized under SI, even though based on the definition $B = \mu_0 H + J$. See footnote c.

j. $\mu_r = \mu/\mu_0 = 1 + \chi$, all in SI. μ_r is equal to Gaussian μ.

k. $B \cdot H$ and $\mu_0 M \cdot H$ have SI units J/m^3, $M \cdot H$ and $B \cdot H/4\pi$ have Gaussian units erg/cm^3.

R.B. Goldfarb and F.R. Fickett, U.S. Department of Commerce, National Bureau of Standards, Bolder, Colorado 80303, March 1985, NBS Special Publication 696. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Table B-2. Recommended SI Values for Physical Constants

Quantity	Symbol	Value (SI units)
Permeability of Vacuum	μ_0	$4\pi \times 10^{-7}$ H m^{-1}
Speed of Light in Vacuum	c	2.9979×10^{8} m s^{-1}
Permitivity of Vacuum	$\varepsilon_0 = (\mu_0 c^2)^{-1}$	8.8542×10^{-12} F m^{-1}
Fine Structure Constant, μ0ce2/2h	α α^{-1}	0.0073 137.0360
Elementary Charge	e	1.6022×10^{-19} C
Plank's Constant	h $h = h/2\pi$	6.6262×10^{-34} J Hz^{-1} 1.0546×10^{-34} J s
Avogadro's Constant	N_A	6.0220×10^{23} mol^{-1}
Atomic Mass Unit	1 u = 10^{-3} kg mol^{-1}/N_A	1.6605×10^{-27} kg
Electron Rest Mass	m_e	0.9109×10^{-30} kg 5.4858×10^{-4} u
Proton Rest Mass	m_p	1.6726×10^{-27} kg 1.0073 u
Neutron Rest Mass	m_n	1.6749×10^{-27} kg 1.0087 u
Magnetic Flux Quantum	$\phi = h/2e$ h/e	2.0679×10^{-15} Wb 4.1357×10^{-15} J Hz^{-1} C^{-1}
Josephson Frequency-Voltage Ratio	2e/h	483.5939 THz V^{-1}
Quantum of Circulation	$h/2m_e$ h/m_e	3.6369×10^{-4} J Hz^{-1} kg^{-1} 7.2739×10^{-4} J Hz^{-1} C^{-1}
Rydberg Constant	R_∞	1.0974×10^{7} m^{-1}
Proton Moment in Nuclear Magnetons	μ_p/μ_N	2.7928
Bohr Magneton	$\mu_B = eh/2m_e$	9.2741×10^{-24} J T^{-1}
Proton Gyromagnetic Ratio	γ_p	2.6752×10^{8} s^{-1} T^{-1}
Diamagnetic Shielding Factor, Spherical H_2O Sample	$1 + \sigma(H_2O)$	1.0000
Molar Mass Constant	R	8.3144 J mol^{-1} K^{-1}
Molar Volume, Ideal Gas (T_0 = 273.15K, p_0 = 1 atm)	$V_m = RT_0/p_0$	0,0224 m^3 mol^{-1}
Boltzman Constant	$k = R/N_A$	1.3807×10^{-23} J K^{-1}
Stefan-Boltzman Constant	$\sigma = (\pi^2/60)\, k^4/h^3\, c^2$	5.6703×10^{-8} W m^{-2} K^{-4}
First Radiation Constant	$c_1 = 2\pi hc^2$	3.7418×10^{-16} W m^{-2}
Second Radiation Constant	$c_2 = hc/k$	0.0144 mK
Gravitation Constant	G	6.6720×10^{-11} N m^2 kg^{-2}

Data (abbreviated to 4 decimal places) from CODATA Bulletin No. 11, ICSU CODATA Central Office, 19 Westendstrasse, 6 Frankfurt/Main, Germany. Copies of this bulletin are available from this office.

APPENDIX C

HALL GENERATORS

C1.0 GENERAL

This chapter provides theory of operation, specifications, mechanical drawings, and definition of terminology. Hall Generator theory of operation is detailed in Paragraph C2.0. Generic Hall generator hookup is detailed in Paragraph C3.0. Hookup to a Model 460 Gaussmeter is discussed in Paragraph C4.0. Specifications of the various available Hall generators are detailed in Paragraph C5.0. Finally, the HALLCAL.EXE program is detailed in Paragraph C6.0. Additional installation and calibration information is available in Lake Shore Document Number F075-00-00 – Hall Generator Application Guide.

C2.0 THEORY OF OPERATION

The Hall effect was discovered by E. H. Hall in 1879. For nearly 70 years it remained a laboratory curiosity. Finally, development of semiconductors brought Hall generators into the realm of the practical.

A Hall generator is a solid state sensor which provides an output voltage proportional to magnetic flux density. As implied by its name, this device relies on the Hall effect. The Hall effect is the development of a voltage across a sheet of conductor when current is flowing and the conductor is placed in a magnetic field. See Figure C-1.

Electrons (the majority carrier most often used in practice) "drift" in the conductor when under the influence of an external driving electric field. When exposed to a magnetic field, these moving charged particles experience a force perpendicular to both the velocity and magnetic field vectors. This force causes the charging of the edges of the conductor, one side positive with respect to the other. This edge charging sets up an electric field which exerts a force on the moving electrons equal and opposite to that caused by the magnetic-field-related Lorentz force. The voltage potential across the width of the conductor is called the Hall voltage. This Hall voltage can be utilized in practice by attaching two electrical contacts to the sides of the conductor.

The Hall voltage can be given by the expression:

$$V_H = \gamma_B B \sin \theta$$

where: V_H = Hall voltage (mV)
γ_B = Magnetic sensitivity (mV/kG) (at a fixed current)
B = Magnetic field flux density (kilogauss)
θ = Angle between magnetic flux vector and the plane of Hall generator.

As can be seen from the formula, above, the Hall voltage varies with the angle of the sensed magnetic field, reaching a maximum when the field is perpendicular to the plane of the Hall generator.

C2.1 ACTIVE AREA

The Hall generator assembly contains the sheet of semiconductor material to which the four contacts are made. This entity is normally called a "Hall plate." The Hall plate is, in its simplest form, a rectangular shape of fixed length, width and thickness. Due to the shorting effect of the current supply contacts, most of the sensitivity to magnetic fields is contained in an area approximated by a circle, centered in the Hall plate, whose diameter is equal to the plate width. Thus, when the active area is given, the circle as described above is the common estimation.

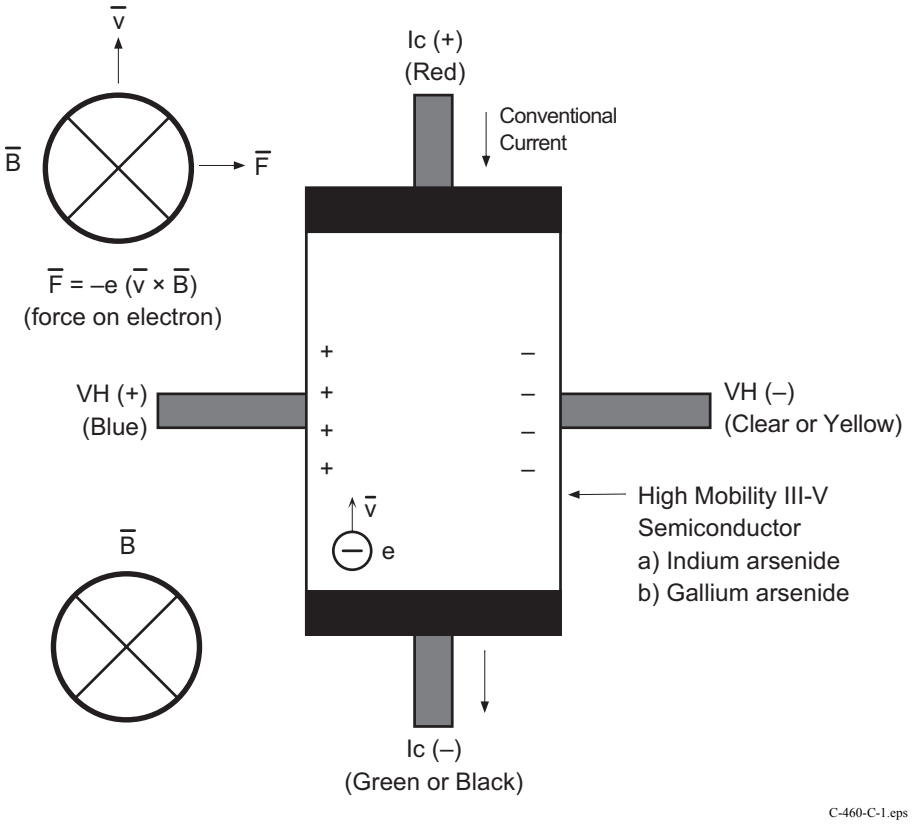


Figure C-1. Hall Generator Theory

C2.2 ORIENTATION

Hall generators come in two main configurations, axial and transverse. Transverse devices are generally thin and rectangular in shape. They are applied successfully in magnetic circuit gaps, surface measurements and general open field measurements. Axial sensors are mostly cylindrical in shape. Their applications include ring magnet center bore measurements, solenoids, surface field detection and general field sensing.

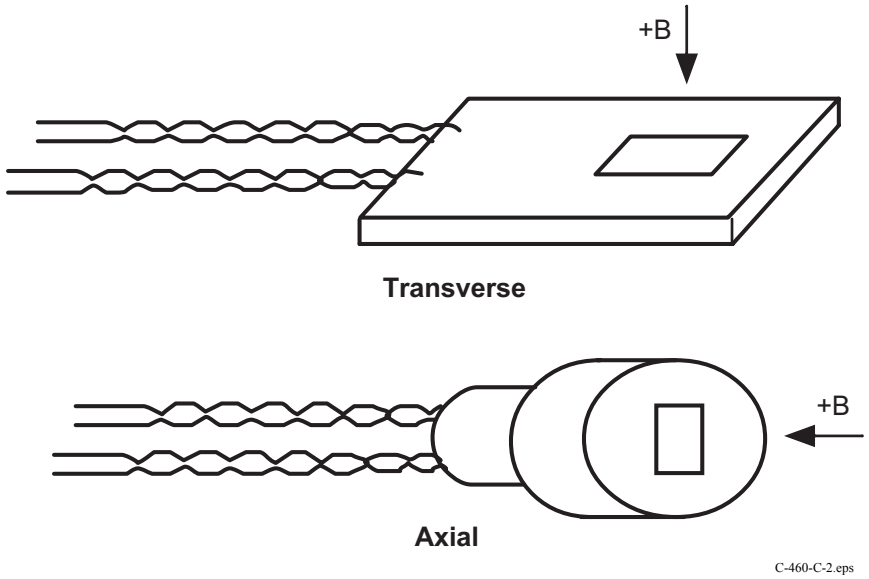


Figure C-2. Axial and Transverse Configurations

C2.3 HANDLING

CAUTION: Care must be exercised when handling the Hall generator. The Hall generator is very fragile. Stressing the Hall generator can alter its output. Any excess force can easily break the Hall generator. Broken Hall generators are not repairable.

Hall Generators are very fragile and require delicate handling. The ceramic substrate used to produce the Hall Generator is very brittle. Use the leads to move the Hall generator. Do not handle the substrate. The strength of the lead-to-substrate bond is about 7 ounces, so avoid tension on the leads and especially avoid bending them close to the substrate. The Hall Generator is also susceptible to bending and thermal stresses.

C2.4 POLARITY

If the control current enters the red lead (with $+I_C$ connected to the positive terminal of the current supply), and the magnetic field direction is as shown in Figure C-2, a positive Hall voltage will be generated at the blue lead ($+V_H$). Reversing either the current or the magnetic field will reverse the output voltage.

C2.5 LEAD CONFIGURATIONS

All Hall generators (except Models HGCA-3020 and HGCT-3020) have 34 AWG solid copper with poly-nylon insulation and have the same lead configuration as follows:

Red = $+I_C$
Green = $-I_C$ } Input (Control Current)

Blue = $+V_H$
Clear = $-V_H$ } Output (Hall Voltage)

The Model HGCA-3020 and HGCT-3020 Hall generators have 34 AWG stranded copper with Teflon® insulation and have the following lead configuration:

Red = $+I_C$
Black = $-I_C$ } Input (Control Current)

Blue = $+V_H$
Yellow = $-V_H$ } Output (Hall Voltage)

C3.0 HALL GENERATOR GENERIC HOOKUP

The Hall voltage leads may also be connected directly to a readout instrument, such as a high impedance voltmeter, or can be attached to electronic circuitry for amplification or conditioning. Device signal levels will be in the range of microvolts to hundreds of millivolts. In this case, a separate precision current source (Lake Shore Model 120CS or equivalent) is necessary. See Figure C-3.

CAUTION: The four Hall generator leads connect to four points on a sheet of semiconductor material having different potentials. No two leads can be connected together without adversely affecting operation. Therefore, the current source and the output indicator cannot have a common connection, but must be isolated from each other. One, the other, but not both, may be grounded.

CAUTION: Do not exceed the maximum continuous control current given in the specifications.

The Hall generator input is not isolated from its output. In fact, impedance levels on the order of the input resistance are all that generally exist between the two ports. To prevent erroneous current paths, which can cause large error voltages, the current supply must be isolated from the output display or the down stream electronics.

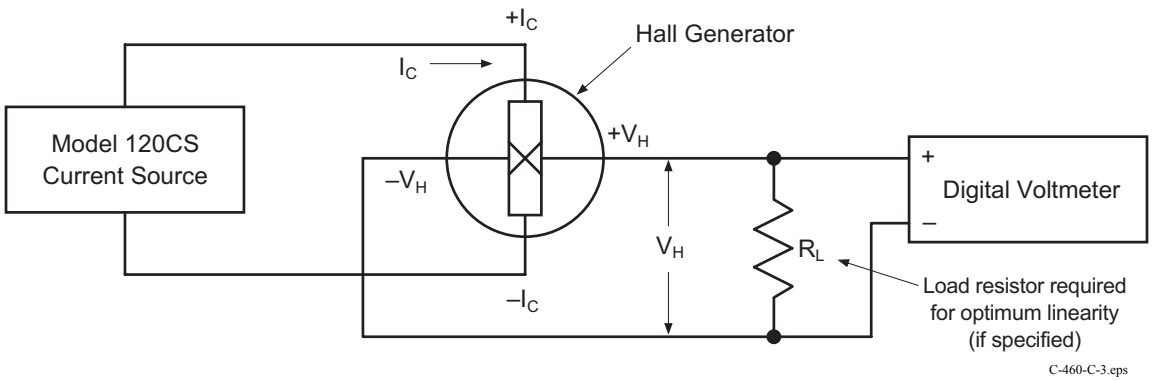


Figure C-3. Typical Hall Generator Hookup

C4.0 USING A HALL GENERATOR WITH THE MODEL 460

To hookup a Hall generator you must use the Lake Shore Model MCBL-6 or -20 Cable Assembly. The cable has a DA-15 connector on one end and four leads on the other. The Hall generator is a 4-lead device. The 4 leads are labeled +Ic (Red), –Ic (Black or Green), +VH (Blue), and –VH (Yellow), corresponding to the 4 leads on all the Hall generators.

The Model 460 has an input impedance of 420 Ω. Therefore, the actual sensitivity at the gaussmeter input will be less than the value given with the Hall generator due to drop in the leads and cable. This fact is important because a sensitivity value is supposed to be loaded into the cable PROM to set calibration. We recommend that the customer always check accuracy against a reference field rather than use the sensitivity value sent with the bare Hall generator. Because Lake Shore has no control of the conditions beyond the cable, the customer must accept responsibility for accuracy and compatibility.

Finally, Manganin wire is not usually acceptable for cryogenic installations. The resistance of Manganin wire is often too high. In cryogenic applications, Hall generators are normally connected using twisted pairs of copper wire such as 34 gauge, Teflon insulated. There are two reasons for this:

1. The gaussmeter current source is normally limited in compliance voltage. The Model 460 should not drive a load (Hall generator, Wires in cryostat, and probe cable) greater than 50 Ω. In fact, for best performance, the load should be less than 30 Ω.

2. Because the Model 460 input impedance is 420 Ω, there is a voltage drop due to lead resistance in series with the gaussmeter input. The Lake Shore Hall generator sensitivity given on the data sheet is basically with no lead resistance. See Figure C-4.

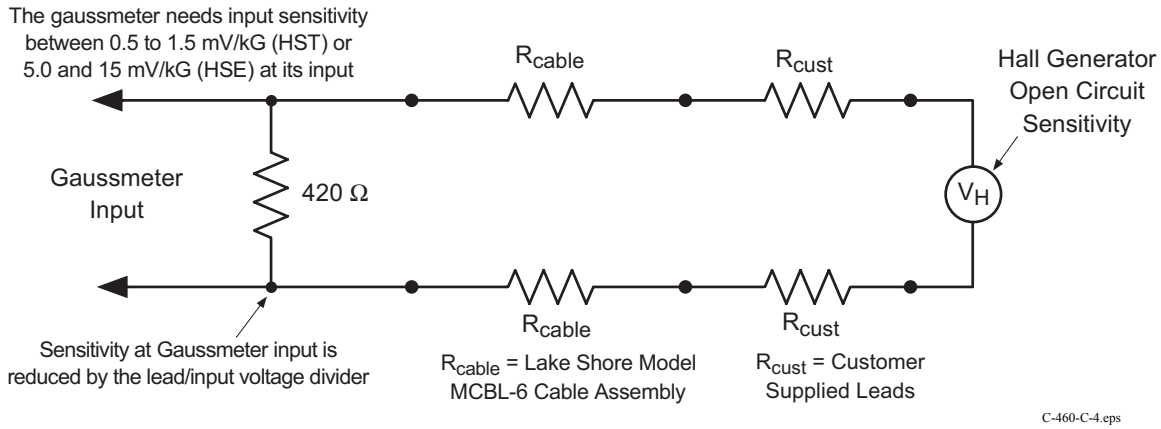


Figure C-4. Hall Generator Input Impedance

C5.0 SPECIFICATIONS

This section covers three types of Hall generators available from Lake Shore: HGCA & HGCT Series Cryogenic Hall generators (Figures C-5 and C-6) with specifications (Table C-1), HGA Series Axial Hall generators (Figures C-5 and C-7) with specifications (Table C-2), and HGT Series Transverse Hall generators (Figures C-8 thru C-10) with specifications (Table C-3).

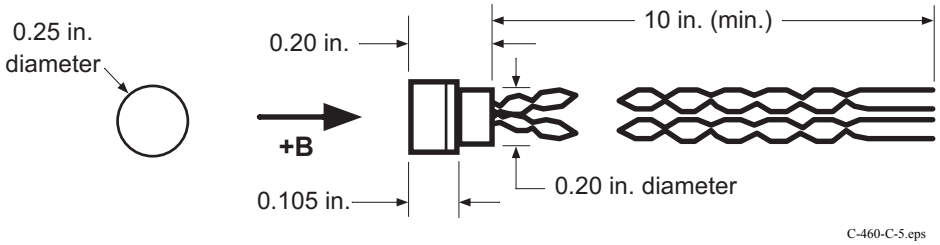


Figure C-5. Axial Hall Generator HGA-3010, HGA-3030, and HGCA-3020 Dimensions

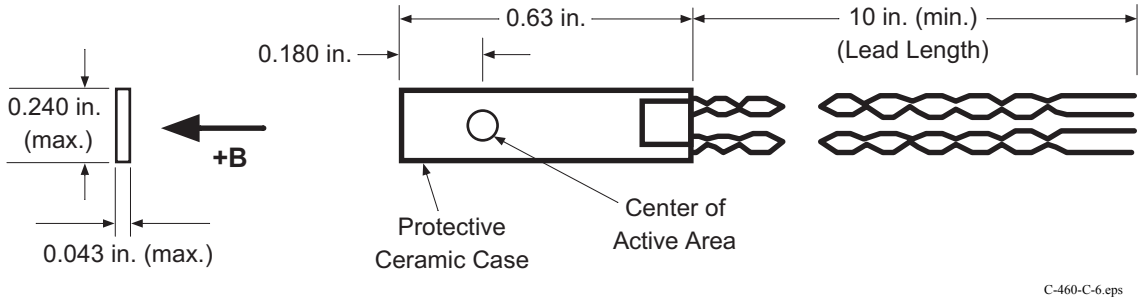


Figure C-6. Transverse Hall Generator HGT-3010, HGT-3030, and HGCT-3020 Dimensions

Table C-1. Cryogenic Hall Generator Specifications

Cryogenic	HGCA-3020	HGCT-3020
Description	Cryogenic axial; phenolic package	Cryogenic transverse; ceramic package
Active area (approximate)	0.030 inch diameter circle	0.040 inch diameter circle
Input resistance (approximate)	1 ohm	1 ohm
Output resistance (approximate)	1 ohm	1 ohm
Nominal control current (I_{CN})	100 mA	100 mA
Maximum continuous current (non-heat sinked)	300 mA	300 mA
Magnetic sensitivity (I_C = nominal control current)	0.55 to 1.05 mV/kG	0.55 to 1.05 mV/kG
Maximum linearity error (sensitivity vs field)	±1.0% RDG (-30 to +30 kG) ±2.0% RDG (-150 to +150 kG)	±1.0% RDG (-30 to +30 kG) ±2.0% RDG (-150 to +150 kG)
Zero field offset voltage (I_C = nominal control current)	±200 µV (max.)	±200 µV (max.)
Operating temperature range	4.2 K to 375 K	4.2 K to 375 K
Mean temperature coefficient of magnetic sensitivity	–0.01%/K (max.)	–0.01%/K (max.)
Mean temperature coefficient of offset (I_C = nominal control current)	±0.4 µV/K (max.)	±0.4 µV/K (max.)
Mean temperature coefficient of resistance	±0.6%/K (max.)	±0.6%/K (max.)
Leads	34 AWG copper w/Teflon insulation	34 AWG copper w/Teflon insulation

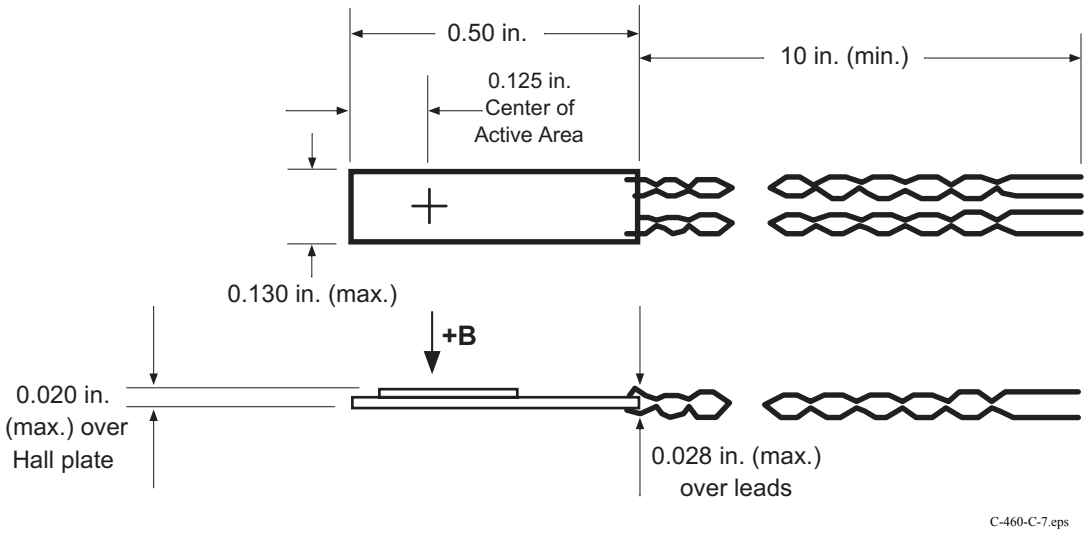


Figure C-7. Transverse Hall Generator HGT-1010 Dimensions

Table C-2. Axial Hall Generator Specifications

Axial	HGA-3010	HGA-3030
Description	Instrumentation quality axial; low temperature coefficient; phenolic package	Instrumentation quality axial; phenolic package
Active area (approximate)	0.030 inch diameter circle	0.030 inch diameter circle
Input resistance (approximate)	1 ohm	2 ohms
Output resistance (approximate)	1 ohm	2 ohms
Nominal control current (I_{CN})	100 mA	100 mA
Maximum continuous current (non-heat sinked)	300 mA	300 mA
Magnetic sensitivity (I_C = nominal control current)	0.55 to 1.05 mV/kG	6.0 to 10.0 mV/kG
Maximum linearity error (sensitivity versus field)	±1% RDG (–30 to +30 kG) ±1.5% RDG (–100 to +100 kG)	±0.30% RDG (–10 to +10 kG) ±1.25% RDG (–30 to +30 kG)
Zero field offset voltage (I_C = nominal control current)	±50 µV (max.)	±75 µV (max.)
Operating temperature range	–40 to +100 °C	–40 to +100 °C
Mean temperature coefficient of magnetic sensitivity	–0.005%/°C (max.)	–0.04%/°C (max.)
Mean temperature coefficient of offset (I_C = nominal control current)	±0.4 µV/°C (max.)	±0.3 µV/°C (max.)
Mean temperature coefficient of resistance	±0.15%/°C (approx.)	+0.18%/°C (approx.)
Leads	34 AWG copper with poly-nylon insulation	34 AWG copper with poly-nylon insulation

Table C-3. Transverse Hall Generator Specifications

Transverse	HGT-1010	HGT-3010	HGT-3030
Description	General purpose transverse; 0.020 inch thick	Instrumentation quality transverse; low temperature coefficient; ceramic package	Instrumentation quality transverse ceramic package
Active area (approximate)	0.040 inch diameter circle	0.040 inch diameter circle	0.040 inch diameter circle
Input resistance (approx.)	2 ohms	1 ohm	2 ohms
Output resistance (approx.)	2 ohms	1 ohm	2 ohms
Nominal control current (I_{CN})	100 mA	100 mA	100 mA
Maximum continuous current (non-heat sinked)	300 mA	300 mA	300 mA
Magnetic sensitivity (I_C = nominal control current)	7.5 to 12.5 mV/kG	0.55 to 1.05 mV/kG	6.0 to 10.0 mV/kG
Maximum linearity error (sensitivity versus field)	±1.0% RDG (-10 to 10 kG)	±1% RDG (-30 to 30 kG) ±1.5% RDG (-100 to 100 kG)	±0.30% RDG (-10 to 10 kG) ±1.25% RDG (-30 to 30 kG)
Zero field offset voltage (I_C = nominal control current)	±100 µV max.	±50 µV max.	±75 µV max.
Operating temperature range	–40 to +100 °C	–40 to +100 °C	–40 to +100 °C
Mean temperature coefficient of magnetic sensitivity	–0.08%/°C max.	–0.005%/°C max.	–0.04%/°C max.
Mean temperature coefficient of offset (I_C = nominal control current)	±1 µV/°C max.)	±0.4 µV/°C max.	±0.3 µV/°C
Mean temperature coefficient of resistance	±0.18%/°C approx.	±0.15%/°C approx.	+0.18%/°C approx.
Leads	34 AWG copper with poly-nylon insulation.	34 AWG copper with poly-nylon insulation	34 AWG copper with poly-nylon insulation

C6.0 HALLCAL.EXE PROGRAM

The HALLCAL.EXE program was developed by Lake Shore Cryotronics, Inc. to allow the interfacing of customer attached Hall generators to the Model 460 Gaussmeter. (Please refer to the Software License Agreement behind the title page of this manual.) This program is provided with the purchase of a Model MCBL-6 or -20 Cable Assembly. Because of the many intricacies involved with proper calibration, the Customer must accept responsibility for the measurement accuracy.

Requirements:

- Lake Shore Model 460 Gaussmeter (connected via RS-232 to the computer in the COM1 port).
- Lake Shore Model MCBL-6 or -20 Cable Assembly.
- IBM or compatible CPU.
- Hall generator meeting the sensitivity ranges given below.
- Calibration or sensitivity constant and serial number of the Hall generator.

Operation:

1. Set the Lake Shore Model 460 Gaussmeter to 300 Baud. Refer Paragraph 3.11 of this User's Manual on how to set the Gaussmeter to communicate at 300 Baud.
2. Insert the 3.5-inch disk and type in the default drive (**A:** or **B:**).
3. Type in **HALLCAL**. This will execute the HALLCAL.EXE program.
4. The program will prompt for the Probe serial number. Any combination of 6 letters or number can be entered. Press **Enter** when this is accomplished.
5. The program will prompt for the probe type (0 or 1).
   Enter "**0**" for Hall generators with sensitivities between 5.5 and 10.5 mV/kG (@ 100 mA current).
   Enter "**1**" for Hall generators with sensitivities between 0.55 and 1.05 mV/kG (@ 100 mA current).
6. The program will prompt for the "Calibration Constant." Enter the magnetic sensitivity in mV/kG at a control current of 100 mA. Remember to account for the 420 Ω input impedance of the Gaussmeter when calculating the proper load resistor to install.
7. The program will display all the values entered along with designated F keys:

F1	Probe Serial Number	ABC123
F2	Probe Type	0
F3	Calibration Constant	X.XXX
F10	Program Probe	
Esc	Exit Program	

8. At this time, if any of the parameters need to be changed, just press the appropriate F key and type in the new value. When everything appears correct, press F10 to program the probe.
9. It takes about 20 seconds to program the probe. After the probe is programmed, press the **Esc** key to exit the program.